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The Arizona Asphalt-Rubber Project Review

Part 1

Evaluation of A-R Pavements Constructed Before 1992

by

Gene R. Morris, P.E.
Consulting Civil Engineer
11701 Hacienda Heights
Dewey, Arizona 86327
Phone: 520-772-3055
Fax: 520-759-9309
Email: genemrpa@aol.com

Douglas D. Carlson
Rubber Pavements Association
1801 S. Jentilly Lane Suite A-2
Tempe, Arizona 85215
Phone: 480-517-9944
Fax: 480-517-9959
Email: dougc@rubberpavements.org

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The Asphalt Rubber Team

A partnership of the

Arizona Department of Transportation and the Rubber Pavements Association

Mission Statement:

To enhance and improve Asphalt-Rubber specifications, test methods, and design practices, that are acceptable to all parties, clearly defined, cost effective, and result in a quality product.

The Arizona Asphalt-Rubber Project Review Part 1

Abstract: In the late 1980s and the early 1990s, the Arizona Department of Transportation (ADOT) designed and constructed many large-scale Asphalt-Rubber (A-R) overlay projects on heavily used highways and Interstates in climatically diverse regions within the state. This study captures the data and field performance analysis of fourteen projects that are now over ten years old. This report is a product of the Arizona Asphalt Rubber Team (ART). The ART is a partnering effort of the Arizona Department of Transportation and the Rubber Pavements Association.

The A-R binder commonly used by ADOT is 80% hot paving grade asphalt and 20% ground tire rubber. The aggregate gradations commonly used with A-R binder in Arizona hot mixes are called open graded and gap graded.

Early in the year 2000, an extensive field performance review and pavement management system analysis was conducted at the request of the Arizona DOT regarding the aged A-R overlay systems. The overlays have been used to rehabilitate Portland Concrete Cement Pavements (PCCP) and aged Asphalt Concrete (AC) pavements. The projects reviewed are from nine to twelve years old. The projects are located in diverse climatic regions from cold and wet to hot and dry and include both light and heavy traffic conditions. The review culminated in several reports, this report is one of a series of reports that document the performance of the thin A-R overlay materials.

The A-R mixtures have performed remarkably well for the last decade. Long-term crack resistance and corresponding low maintenance costs appear to be unique in A-R pavements.

Project data is presented in tabular format using percent cracking, rutting, skid resistance, ride and maintenance costs as benchmarks. General mix design information and recent photographs of the projects are included.

KEY WORDS

Asphalt rubber, overlay, friction course, open graded, gap graded, long term pavement performance, reduced maintenance, resistance to cracking.

INTRODUCTION

In the last ten years the Arizona Department of Transportation (ADOT) has constructed over 2500 miles of pavement overlays using asphalt-rubber hot mixes (Fig. 18). Asphalt-Rubber binder is defined by the American Society for Testing and Materials standard specifications (ASTM D 6114-97) as a mixture of 85% hot paving grade asphalt and a minimum of 15% ground tire rubber. However, the A-R binder commonly used by ADOT is 80% hot paving grade asphalt and 20% ground tire rubber. The asphalt and rubber are combined at high temperature and reacted until elastomeric properties are obtained.

Two different hot mix designs are used, dependent on pavement type, field conditions, and climate. One mix, used solely as a surface course, is an open-graded mixture with design air voids of a minimum of 15%. This mix generally has 9% or more binder and has high friction characteristics. The second mix is essentially a dense graded mixture designed to have approximately 5% air voids. However, portions of the smaller aggregate and fines in this mixture are significantly reduced to provide a gap grading. The product is very similar to what is known as a stone-mastic (SMA) mixture with the elastic reacted rubber used in place of inert fillers. The binder content in this mix will generally fall between 7.5 and 8.5%. A comparison of the aggregate gradations for Gap and Open mixtures is exhibited in Figure 1. ADOT nomenclature for the open graded mix is Asphalt-Rubber, Asphalt Concrete Friction Course (AR-ACFC). The Gap-graded mix is Asphalt-Rubber, Asphalt Concrete (AR-AC). The specifications used by ADOT for the A-R binder and mixes are provided in Appendix A.

The AR-ACFC has had extensive use over both Portland Cement Concrete Pavements (PCCP), and asphalt concrete (AC) Pavements. Where used directly on the existing concrete pavement, the design thickness is one inch. Where used in connection with an AC pavement overlay, recycle, or new pavement layer the thickness of the AR-ACFC placed is one half inch. The AR-AC has also been used over both PCCP and AC pavements. In cases where structural improvement is required it may be used in conjunction with a half inch AR-ACFC. This mixture is generally less than two (2) inches in thickness and in most cases is one to one and one half inches (1-1.5) thick. In addition two A-R stress absorbing membrane inter-layers were constructed.

Fourteen full-scale projects using these systems are now over ten years old and are discussed in this review. For and in co-operation with the ADOT, the Rubber Pavements Association (RPA) undertook the task of conducting long-term field performance evaluations of the projects constructed in 1991 and earlier. The projects reviewed included overlays of PCCP and AC, were subject to various traffic loadings and were located in diverse climatic zones, ranging from very hot desert conditions (Maximum air temperature = 124°F, rainfall 4 inches per year) to severe cold (Minimum temperature -31°F , 100+ inch snow, and 28 inches rain.)

In addition to the field reviews, the data in ADOT pavement management system was also reviewed and is presented where applicable. The authors express their gratitude to ADOT for making PMS data, photographs, tables and charts available for this report.

The projects are grouped by overlay type, AR-ACFC or ARAC, and by the type of pavement upon which the overlay has been placed, rigid (PCCP) or flexible (AC). One noteworthy project (I-40, Walnut Canyon) combined the use of AR-ACFC and ARAC over a rigid pavement, but will be discussed in the AR-ACFC over rigid pavement group.

The first grouping of projects presented will be AR-ACFC overlay systems of rigid pavements. The projects are:

Interstate 19, Tucson South MP 58-60 constructed 1988

Interstate 19, Irvington Road MP 60-64 constructed 1991

Interstate 17, Buckeye Rd. – Van Buren MP 198.2-199.8 constructed 1990

Interstate 40 Walnut Canyon MP 195.08 – 205.2 constructed 1990

The second group of projects are AR-ACFCs over flexible pavements. They are:

Interstate 8, Aztec County Line, MP 72-82 constructed 1990

State Route 68, Bullhead City-Kingman, MP 8.1-13 constructed 1991

State Route 77, Glenn Street to Rillito Street Bridge, MP 69.3-71.8 constructed 1990

The third group of projects discussed are the ARAC over flexible pavements. They are:

Glendale, 51st Ave, Northern – Butler, constructed 1991

Glendale, Camelback Road, 43rd-75th Ave, constructed 1991

State Route 77, Ina Road-Canada del Oro, MP 74.9-79.1, constructed 1990

State Route 260, Lakeside-Pinetop, MP 351-354, constructed 1991

State Route 160, Long House Valley, MP 365.0-372.5, constructed 1989

State Route 264, SR 87- Pollaca Wash, MP 384-392.3, constructed 1989

State Route 191, Klagetoh-Ganado, MP 397.0-402.7, constructed 1991

RIGID PAVEMENT OVERLAYS

Interstate 19, Tucson South MP 58-60 Construction 1988

This project is a four lane, divided highway located on the edge of urban Tucson at an elevation of 2584 feet. The climate is moderate desert with maximum air temperature of 111°F and a minimum of 16°F. The typical annual traffic is 400,000 Equivalent Single Axle Loads (ESAL), with a total of 4,800,00 ESALS on the overlay since construction. This was the first full-scale non-experimental project constructed with a thin asphalt-rubber hot mix overlay. It consisted of a one inch thick AR-ACFC placed over a jointed, non-doweled 9 inch PCCP. The PCCP is 24 feet wide and is reinforced at the centerline with tie bars. The PCCP was built in 1965, the overlay was designed to improve the rough ride and poor skid resistance that had developed over 23 years of service. The length of the project is 2 miles. The ADOT pavement management system (PMS) contains the following data:

Table 1. Interstate 19, Tucson South MP 58-60 Performance Data

Performance Indicators	Values Before Overlay	Values 12 Yrs After Overlay
Ride IRI	172	70
Skid (Mu Meter)	38	64
Rutting	N/A	0.11
% Cracking	6%	1%
Maintenance Costs/lane mile/year	$857	$50

Maintenance values for the overlays are averages taken over the life of the project.

At the time of placement the design binder content was 10%. With this open-graded mix this correlates with an aggregate volume of 55%, binder volume of 25%, and air voids of 20%. In the 12 years of service the air voids have decreased to 15%. The original binder at time of placement had a penetration of 48 and a softening point of 140°F. After 12 years of service the penetration has decreased to 22 and the softening point increased to 160°F. This represents excellent resistance to aging. This inspection concluded that this overlay is still in excellent condition. There is no discernable rutting nor is there any evidence of maintenance repairs. There is a very limited number of reflective cracks above the underlying joints and these cracks are all hairline in width or they are “ghost” cracks and are completely closed in the wheel paths. Noise measurements were not made but there is a very discernable difference in noise level between this pavement and the adjacent concrete pavements. The overlay mixture is still alive and exhibits a high level of elastic rebound. Before and after photographs are presented as Figure 2.

Interstate 19, Irvington Road – MP 60-64 1991 constructed 1991

In 1991 an additional four-miles of I-19 was resurfaced with the same type of overlay. This project has the same traffic and environmental exposure as the one previously discussed. At present this pavement has less than 2% reflective cracking with no visible maintenance. Cracks appear above some joints but have not required any maintenance activities such as crack filling or patching. Those cracks that have reflected through, are closed in the wheel paths, and do not appear to suffer from spalling or loss of material. The binder appears to be holding the mix together very well on both sides of these hairline cracks. The worst case of cracking on this project is exhibited in Figure 3, which also includes a representative "before" photographs. The PMS data is similar to the earlier and adjoining project and is represented in Table 2. The high maintenance costs before the overlay are representative of repairs made to approximately eight concrete slabs which had experienced faulting according to the ADOT project materials design memorandum dated January 11, 1991.

Table 2. Interstate 19, Irvington Road Performance Data

Performance Measures	Values Before Overlay	Values 9 Yrs After Overlay
Ride IRI	209	72
Skid (Mu Meter)	36	65
Rutting	N/A	0.1
% Cracking	6%	2%
Maintenance Costs/lane mile/year	$1,476	$50

Incidentally, the cost of the one-inch overlay on this project was $3.64 per square yard.

Interstate 17, Buckeye Rd. – Van Buren MP 198.2-199.8 constructed 1990

The next project is located on Interstate 17 between Buckeye Road & Van Buren in urban Phoenix and was constructed in 1990. This project is located on the northbound freeway in urban Phoenix and the one inch thick AR-ARFC was placed over three twelve foot lanes of PCCP originally constructed in 1960 with a thickness of nine inches plus a ten foot distress lane of AC. After thirty years of good structural performance the PCCP had met the end of its design life. Considerable warping and curling had occurred. The ride was very rough, producing a harmonic bouncing motion in vehicles traveling upon it. Most joints were severely spalled producing a very rough ride are very noticeable tire noises as vehicle tires passed over them. Extensive patching was conducted at the joints an example of which can be seen in Figure 4.. Approximately forty full slabs were replaced prior to overlay.

The Phoenix climate is somewhat hotter than Tucson with a maximum air temperature of 122° F. A typical "summer" will produce one hundred days with temperatures over one hundred degrees. The elevation is 1117 feet. Perhaps more importantly, the traffic level has averaged 2,100,000 ESALS over the last ten years. The Arizona PMS statistics for this project are listed in Table 3.

Table 3. Interstate 17, Buckeye Rd –Van Buren Performance Data

Performance Measures	Before Overlay	10 Years After Overlay
Ride (IRI) inches/mile	179	65
Skid (Mu Meter)	28	57
Rutting	N/A	0.11
% Cracking	N/A	0%
Maintanance Costs $/lane mi/year	$1,200	$256

The 2000 inspection revealed the following conditions.

1) All joints had reflected through in the distress lanes and the shoulder but the cracks were either closed or hairline in the travel lanes.
2) Some structural failure is occurring with three potholes developing. The holes are relatively inline with each other. The pattern suggests underlying repair work to the longitudinal joints prior to the overlay.
3) Noise reduction is good.
4) Ride is smooth and rutting is insignificant.
5) Overlay color is still a very dark black which provides good contrast to pavement markings, striping, and reflectors.

Photographs from the recent inspection are displayed in Figure 4. All in all this pavement is in good condition and the overlay has provided excellent service over it's ten year life.

Interstate 40 Walnut Canyon MP 195.08 – 205.2 Overlay Constructed 1990

The last PCCP overlay discussed is a 10-mile project on Interstate 40 near Flagstaff, Arizona. In contrast to the Phoenix and Tucson projects, this pavement is subject to severe cold weather and is in a moist environment. Flagstaff has an elevation of 7000 feet and the climate is alpine in nature. Minimum temperature may be as low as -30°F and the average annual snowfall is 100 inches. High temperatures seldom are above 90°F with the highest reading of 94°F since construction of this project. In addition, the area experiences an average of 28 inches of rain annually. The area is classified by the Long-Term Pavement Performance (LTPP) program as a "wet freeze" climatic region similar to the northeastern section of the United States. Interstate 40 is a main East-West commercial route and traffic volume is heavy ranging from 1,500,000 ESALS in 1989 to 2,500,000 in 1998 with thirty five percent of the volume attributed to large trucks.

This original pavement was built in 1969 and is a nine-inch non-reinforced (except centerline tie bars), non-doweled, typical, four lane divided Interstate highway. The ten foot right distress lane and four foot left shoulder were AC materials. Documents and discussions with ADOT engineers revealed that the pavement began to fail in 1974, five years after construction because of faulty base materials. Failure included faulting of ½ inch and more, large corner cracks, transverse cracking and severe spalling of the joints. By 1980, cracking reached 9%, ride quality had deteriorated from 100 inches/mile to 160 inches/mile and maintenance costs were excessive at $6,227.00 per lane mile. Design began in 1988 and reconstruction was an obvious consideration. Examination of this alternate indicated that reconstruction would cost an estimated $30,000,000 and that a 4-year time for construction would be required. It was finally concluded that financial restraints would not permit reconstruction, therefore, various overlay alternates were considered.

The final design included edge drains, crack and seat of the PCCP, a 3 inch conventional AC layer followed by a 2 inch AR-AC and a ½ inch AR-ACFC. By using an A-R overlay as an alternate to reconstruction reduced the cost of the project by $18,000,000 and reduced construction time from four years to six months.

The performance of this design has been phenomenal. The 1998 PMS data show 0% percent reflective cracking, IRI of 63 in/mile, rut depths of .11 inches, skid resistance of 65, maintenance costs per mile ranged from 0 in 1990 to $852 in 1998. The project performance values are contained in Table 4 below. Photographs of the project are exhibited in Figure 5.

Table 4. Interstate 40, Walnut Canyon Performance Data

Performance Indicators	Values Before Overlay	Values 10 Yrs After Overlay
Ride inches/mile	160	63
Skid (Mu Meter)	41	65
Rutting	N/A	0.11
% Cracking	9%	0%
Maintenance Costs/lane mile/year	$6,227	$800

The inspection in the year 2000 verified this performance. Reflective cracking is still near zero and the ride is excellent. Maintenance activities are primarily on the shoulders and within localized areas which are discussed next.

Of particular interest in the I-40 project is that it includes eight Strategic Highway Research Program (SHRP) test sections and 10 state test sections under LTPP Specific Pavement Studies for rehabilitation of jointed PCCP. The experimental sections are referred to as SPS-6. Upon visual inspection, maintenance activities such as crack sealing and patching are observed mostly within the test sections. The test sections reviewed in this paper ranged from 4 to 8 inch AC overlays over rubbilized or cracked and seated PCCP. The individual sections are subject to another report. A copy of the test section layout is included in Figure 6. Photographs of the sections are displayed in Figure 7. The year 2000 survey has the following selected comments:

State Test Section 040660, 8 inch conventional AC overlay of rubbilized PCCP – "has transverse cracks at 50 feet spacing which are one half inch to one inch wide. Longitudinal cracking occurs at the centerline and between wheel paths. Ride is already rough. It is estimated that the pavement will have to be replaced within 2 years."

SHRP Test Section 040607, 4 inch overlay of Cracked and Seated PCCP - "this pavement has one inch wide cracking at approximately 12 feet centers and longitudinal cracking at the center line. Cracks are spalling in the travel lane."

State Test Section 040661, two inch ARAC, over two inch AC, C and S PCCP - "this pavement is in excellent condition, it has a few 1/8 inch wide transverse cracks and hairline longitudinal cracks between wheel paths, no spalling, little maintenance evident on driving lanes, some crack sealing on the shoulder lane."

SHRP Test section 40604, four inch AC overlay, saw and seal joints. "The joints have reflected through and are open ½ to 2 inches. They have been resealed but exhibit extensive spalling. There are continuous, wide, longitudinal cracks at the center line. Some rutting is evident."

The SHRP maximum restoration, minimum restoration, and control sections, are all "out of study". The SHRP control section apparently received an AR-ACFC in August of 1993 and is performing fairly well although it has cracking at every joint.

In comparison the overlay design for the entire ten miles is in excellent condition with little or no cracking and very little maintenance evident.

FLEXIBLE PAVEMENT OVERLAYS WITH AR-ACFC

The next group of projects examined in the year 2000 review were the AR-ACFC overlays of flexible pavements. These projects were placed in a diverse range of climate and traffic conditions. Two of the projects are discussed in this report.

Interstate 8, Aztec County Line MP 72-82, constructed 1990

The first friction course placed over aged AC is located between Gila Bend and Yuma, a desolate, extreme desert climate. The area is at an elevation of 870 and has maximum temperature of 120°F. This region is often reported as the hottest in the USA in the summer months. In 1990, the existing pavement was badly cracked, a ride of 70, with rut depth 0.36 inches and maintenance cost running $1841 per lane mile. The rehabilitation design for this project consisted of a four inch AC overlay with a ½ inch AR-ACFC. Project photographs are contained in Figure 8. After 10 years of service the pavement had 3% cracking, a ride of 46, rut depth of 0.05 inches, and maintenance costs average of $126.20 per lane mile. There is no bleeding and skid resistance is still very high with a Mu meter reading of 60. See Table 5 for project data.

Table 5. Interstate 8, Aztec- County Line, MP 72-82 Performance Data

Performance Indicators	Values Before Overlay	Values 10 Yrs After Overlay
Ride inches/mile	70	46
Skid (Mu Meter)	38	60
Rutting	0.36	0.05
% Cracking	3%	3%
Maintenance Costs/lane mile/year	$1,841	$126

State Route 68, Bullhead City-Kingman, MP 8.1-13, constructed 1991

An example of the typical service of the thin (½ inch) AR-ACFC placed on a two-lane highway, SR 68 in 1991. This road is also in extreme high temperature with maximum air temperature of 124°F and a minimum of 14°F. In addition, this eight mile long project is located on steep grades, virtually over the entire length. In 1991 the existing thin 2.3 asphalt pavement had 55% cracking and associated maintenance cost of $1500 per lane mile. The ride level was 115 inches per mile with rut depths of 0.35 inches. ADOT PMS reports 0% reflective cracking the first five years after the one-inch AR-ACFC was placed and only 1% in the next three years. The ride is 75 with maximum rut depth of 0.27 inches. Maintenance costs have averaged less than $150 per lane mile. The year 2000 inspection showed this highway still to be in excellent condition with a very low percentage cracking. The cracks that have reflected through are hairline and have not required maintenance. While this is a low traffic route, it is carrying a volume of 110,000 18 kip ESALs. Project performance data are available in Table 6 and photographs are displayed in Figure 9.

Table 6. SR 68, Bullhead City-Kingman MP 8.1-13 Performance Data

Performance Indicators	Values Before Overlay	Values 9 Yrs After Overlay
Ride inches/mile	115	75
Skid (Mu Meter)	57	63
Rutting	0.35	0.27
% Cracking	55%	1%
Maintenance Costs/lane mile/year	$1,500	$150

FLEXIBLE PAVEMENT OVERLAYS WITH AR-AC

There are nine projects included in the AR-AC overlay group. Three of the AR-AC projects are thin overlays of urban arterial streets in desert climatic zone and a forth is similar traffic, but much colder weather. Five projects have very light traffic are serving well with very little maintenance, but appear to be badly oxidized. The inspections produced the following observations.

Glendale, 51st Ave, Northern – Butler, constructed 1991

This project is located within the City of Glendale, a northwestern suburb of Phoenix and was constructed in 1991. Although this project was administered by ADOT during design and construction it is not part of the ADOT system and no PMS data is available. This is a one-mile section of a four lane, arterial street with a continuous left turn lane in the center. It has traffic signals at each end and one at the half-mile intersection. Approaching and leaving the signalized intersections, transverse cracks are present in the southbound driving lanes at approximately twelve feet on center. These cracks are closed in the wheel paths and are narrow elsewhere except for the turn lane where the cracks are a quarter inch in width. Moving away from the intersections, the cracking in the travel lane becomes less prominent. The cracks are hairline in nature, and stop entirely approximately 300 ft. from the intersection. In the continuous median, left turn lane, the cracks continue throughout the length the project. Some curling of the crack edges can also be noted in the median lane. Of further interest is that cracking in the travel lanes occurs only in the southbound lanes and not in the northbound lanes. Photographs of the project are displayed in Figure 10.

Discussion:

The effect of traffic on the pavement performance is pronounced. In non-traffic or light traffic areas, the amount of cracking is far more extensive and is much more severe. The conclusion is that the traffic is good for these elastic materials. Two possible explanations are:

1.) Traffic is "kneading" the pavement and healing the cracks.

2.) The normal forces created by the moving wheel loads are opposite to the shrinkage, curling, and warping forces and thus reduce the overall tensile stress on the pavement section.

Observations from the project also reveal that acceleration and deceleration forces imposed by traffic has an effect on cracking, but a relatively minor one. As to why the northbound lanes have no cracking as compared to the southbound one can only conjecture that possible reasons are:

1.) The southbound lanes carry the inbound traffic to central Phoenix and thus have heavy traffic in the mornings when the pavement is colder and is more susceptible to cracking (likely).

2.) Some unknown construction sequence developed improved pavement only in the northbound lanes (unlikely).

All in all, this pavement is in good to excellent condition, there is no indication of maintenance, and the ride performance was smooth.

Glendale, Camelback Road, 43rd Ave. to 75th Ave, constructed in 1991

This project (four miles in length) is in the same general area as the 51st Ave. project and has similar traffic and climatic conditions. It was also constructed for the city of Glendale as an

ADOT administered program. Likewise, no PMS data are available. As one would expect performance would be very similar. Photographs are in Figure 11. Transverse cracks have developed with approximately 15 feet centers in the median or center turn lane. The cracks are a quarter inch or greater in width and curling can be observed. Cracking in the travel lanes is limited to the stopping and starting areas and the cracks are hairline and fully closed in the wheel paths. The transverse cracks in the center lane do not appear in the travel lanes.

There is an area of fatigue failure in the westbound curb lane west of 55th Ave. This failure is localized, approximately 180 feet long and two feet wide. Soil strains from pumping and differential settlements are noted in this area. The cracks that have formed are a chicken wire pattern, 3-4 inches apart, and are hairline. There is no spalling and no pot-holing, however repairs should be made.

Some minor pitting has occurred and the pavement appears to have been flushed at some point in the past. Overall, though, the pavement is still in excellent condition.

State Route 77, Ina Road - Canada Del Oro, MP 74.9-79.1 constructed 1990

Another project in this same category is the State Route 77 project in Tucson from Ina Road to Canada Del Oro. This is an urban area arterial street, four lanes, slightly over 4 miles in length. It was constructed in 1990. This project used an AC-10 asphalt. The asphalt content was 8.8% with a high asphalt absorption of .69%. The design void was 6% with a VMA of 23.4 and the overlay thickness is ½ inch.

Before the overlay, this pavement had an extremely high maintenance cost of $7971/lane mile, even though the percentage cracking was low (7%) and the ride was good (54). In the ten years since the overlay maintenance cost have averaged only $394 per year. PMS data is presented in Table 7 below and photographs are in Figure 12.

Table 7. SR 77, Ina Road –Canada del Oro MP 74.9-79.1 Performance Data

Performance Indicators	Values Before Overlay	Values 10 Yrs After Overlay
Ride inches/mile	54	53
Skid (Mu Meter)	58	62
Rutting	0.15	0.17
% Cracking	7%	1%
Maintenance Costs/lane mile/year	$7,971	$394

State Route 260 Lakeside-Pinetop M.P. 351-354 constructed 1991

The fourth project is in similar traffic conditions, but is located in a moderately severe climatic zone. This project is at 6400 feet elevation with minimum air temperature of –25° F. Average snowfall is 30 inches annually with rainfall of 15.4 inches. The mix design used for this project is similar to the others with VMA of 20.6, design air voids of 5.1% and an asphalt content of 7.6%. The asphalt used was an AC-10. The pavement is a four-lane roadway with a continuous left turn lane or median lane. A signalized intersection exists at the west end of the project. The pavement approaching from the west of this project is badly cracked, it has one to two inch cracks spaced at 75 feet plus or minus centers. These cracks have severe spalling, have been sealed, but the crack edges are warped. As you drive through the section every crack can be felt (and heard) and the ride is very poor. As you enter onto the project narrow cracks occur for the first 1500 feet. Initial spacing is about fifty feet and increases to 300 feet as you leave the stop light area. There again, the cracks are wider in the left turn lane. The center 2 miles of this project are essentially crack free, even in the left turn lane. This is in a commercial area and evidently there is sufficient left turn traffic to prevent cracking from non-use as observed in other projects with center lanes.

In the Eastern ½ mile of the project both longitudinal and transverse cracking have developed. The transverse cracks are spaced at approximately 20 feet and are ¼ inch to ½ inch wide in the travel lanes. These cracks have been sealed by maintenance. These cracks are not spalling, warping or cupping is not evident, and the ride is still excellent.

The rating for this ½ mile would have to be fair to good with the remaining 2½ mile, considered in excellent condition. Performance data is listed in Table 8 and photographs are available in Figure 13.

Table 8 State Route 260 Lakeside-Pinetop MP 351-354 Performance Data

Performance Indicators	Values Before Overlay	Values 10 Yrs After Overlay
Ride inches/mile	80	65
Skid (Mu Meter)	46	55
Rutting	0.25	0.12
% Cracking	2%	1%
Maintenance Costs/lane mile/year	$2,500	$650

Three of the AR-AC projects were constructed on relatively low traffic, two lane roadways in moderately severe climatic conditions. The projects are located on the Navajo Indian Reservations. Each of these are evaluated as follows.

State Route 160, Long House Valley MP 365.0-372.5 constructed 1988. This project extends from MP 345 to 372 and consists of a 1½ inch AR-AC over the existing pavement which was 2½ inches AC over 6 inches of granular base. This project is located on a high desert mesa at an elevation of slightly over 5000 feet. Maximum air temperature is listed at 109° F with a minimum temperature of –20° F. The average snowfall is 5 inches and rainfall is 7.4 inches. Freezing index is 550.

The asphalt used on the project was a AC-10 at 6.7% content and the aggregate had asphalt absorption of 0.44%. Prior to overlay, the section had 22% cracking, rut depths of .29 inches, and required an expenditure of $4900/lane mile to maintain the roadway. The overlay was constructed in 1989. Because of the cracking, the ride IRI on this roadway had reached 211. After 11 years of service the PMS systems shows ride of 128 in/mile, rut depths of 0.16 inches and average annual maintenance cost of $980/lane mile.

Traffic is moderate at 90,000 ESALS/years. Approaching this project from the west on a conventional AC material, there is extensive, wide, transverse, and longitudinal cracking. The ride is very rough and each transverse crack can be distinctly felt. The transverse cracks are about 50 feet apart, one inch (plus) in width, are spalling, and curling downward. These cracks have been sealed but the ride is unpleasant and sufficiently rough to probably result in increased operating vehicular operating costs.

Within the project, some cracking exists in the overlay. For the most part this consists of transverse cracks approximately 40-50 feet apart, ¼ inch wide in shoulder area and closed in the traffic lanes. There is no spalling or curling evident and with very few exceptions, there has been no maintenance. Near the center of the project, Peabody Coal Company has a terminal. West of this in the westbound lane there exist some fatigue cracking. These chicken wire cracks are hairline in nature, and are not spalling. This area probably will require some maintenance expenditure in the near future. In the west three-miles of the project are areas of transverse cracking, 1/8-1/4 inches wide but closed in wheel paths. No curling, no spalling, or raveling has occurred. All in all, after 11 years of service, this pavement is still in excellent condition. The asphalt mix itself, however, does appear to be dry and aged. This is probably the result of initial mix design characteristics and will be discussed at the end of this specific three project evaluation.

Table 9 State Route 160 Long House Valley MP 365-372.5 Performance Data

Performance Indicators	Values Before Overlay	Values 10 Yrs After Overlay
Ride IRI	211	128
Skid (Mu Meter)	66	69
Rutting	0.29	0.16
% Cracking	22%	6%
Maintenance Costs/lane mile/year	$4,900	$980

Route 264, Jct. Route 77 to Pollaca Wash 384.8-392.3 constructed 1989. This project is located on a high, desert, plateau at an elevation of 6340 feet. The climate is fairly severe with maximum air temperature of 102° F and minimum air temperature of –27° F. Average annual snowfall is 29 inch with an average rainfall of 10.9 inches. The freezing index is 800. This overlay consisted of a gap-graded AR-AC over the existing pavement section of four-inch granular base and three-inch asphalt concrete. The overlay mix used an AC-10 at 6.5% binder content. Before the overlay the pavement exhibited 10% cracking, had a ride level of 153 IRI and a maintenance cost of $2100 per lane mile annually. After nine years the overlay had 7% cracking, ride level of 106, and an average maintenance cost of $835 per lane mile annually. Traffic is light at 30,000 ESALS/year. The present 11-year evaluation found transverse shrinkage cracks, ¼ to ½ inch wide, approximately 35 feet spacing. These cracks are open with some spalling outside of the wheel paths. For the wheel paths the cracks are either closed (hairline) or have a maximum of 1/8 inch opening. None of these have required any maintenance. If one deliberately steers outside of the normal wheel paths, the presence of the cracks can be noticed in the ride quality. Overall, however, the ride is good to excellent.

Table 10. Route 264, Jct. Route 77 to Pollaca Wash 384.8-392.3 Performance Data

Performance Measures	Values Before Overlay	Values 9 Yrs After Overlay
Ride IRI	209	72
Skid (Mu Meter)	36	65
Rutting	N/A	0.1
% Cracking	6%	2%
Maintenance Costs/lane mile/year	$1,476	$50

Route 191, Klagetoh - Canado MP 397-402.7 constructed 1991.

This is 1.5 inches AR-AC placed over an old pavement consisting of four-inch granular base and three-inch AC surfacing. The mix design for this pavement called for an AC-10 asphalt at 6.5%. Asphalt absorption was .23% with 1% cement added for anti-strip protection. This project is in a high desert area with maximum air temperature of 107° F and a minimum temperature of –27° F. Average snowfall is 29 inches with average rainfall of 10.9 inches. Before the overlay the roadway had 19% cracking and a ride of 105 with rut depths of three inches. Maintenance cost was $5972/ lane mile. After eight years of service the pavement exhibited 1% cracking, a ride of 86 and rut depth of .17 inches. During this entire eight years maintenance cost totaled only $205.

In the year 2000 the observations were noted. Each end of the project is in a terrain of rolling hills. In these areas transverse cracks have developed at approximately 20 feet centers. The cracks are ¼ - ½ wide in the non-traffic areas and are hairline or less than 1/8 inch in the wheel paths. The center section of the project lies in a broad valley which is relatively level. In this section very few cracks exist and are less than 1/8 inch. Two possible explanations of this behavior would be that the level areas had lower stress both from environmental and traffic applications from the areas on the grades. It is also possible that during construction those sections on grades were not as well compacted and the pavement experienced slightly more aging. After nine years of service in fairly severe climatic conditions, this pavement is still in good to excellent condition.

Table 11. Route 191, Klagetoh - Canado MP 397-402.7 Performance Data

Performance Measures	Values Before Overlay	Values 9 Yrs After Overlay
Ride IRI	105	86
Skid (Mu Meter)	36	65
Rutting	N/A	0.17
% Cracking	19%	1%
Maintenance Costs/lane mile/year	$5,972	$205

The mix design was very similar on each of these projects. Binder content was 6.5 to 6.7%, VMA's were about 18, final air voids 3.8 to 4.7% with Marshall blows of 9 to 13. All had asphalt absorptions of .32 to .44%. All used on AC-10 asphalt. Observation on all three projects was that the pavements appeared to be oxidized and somewhat brittle. We believe that the following might be considered for AR-AC pavements in cold climatic regions.

A) Lower asphalt grade by at least one grade below that recommended for standard AC pavements.

B) Increase VMA's to a minimum of 23.

C) Increase binder content to provide for 3 to 4% air voids.

We believe that these suggestions will provide a pavement that will be more resilient to cracking of all types and will still be highly resilient to rutting.

CONCLUSIONS

Visual inspection of the eighteen asphalt rubber projects that are ten or more years old indicate that the pavements are performing extremely well. Examination of available PMS indicate very low cracking rates and maintenance costs. The following conclusions are drawn:

1. Considering the PCCP overlays – the AR-ACFCs have performed far beyond the expectation of any known alternative rehabilitation strategies or overlay materials that are currently available and economically competitive.
2. The AR overlay strategies employed by ADOT have performed well in a diverse range of climates from cold and wet to hot and dry.
3. The overlay design strategies used by ADOT for AR materials performed extremely well under diverse loading conditions from light to very heavy traffic. The loading a ranged from 110,000 18 kip ESALs per year for rural two lane highways to 2,100,00 18 kip ESALs per year on multi lane urban Interstates.
4. The AR-ACFCs with binder contents of an average 9% demonstrated greater resistance to crack reflection than corresponding ARAC mixes with lower binder contents. The appearance of oxidation was much less in the mixes with higher binder contents. When cracking occurred, no raveling or spalling occurred.
5. None of the projects exhibited any binder stripping, all projects used an AC-10 or AC-20 base asphalt for the binder.
6. No bleeding or flushing has occurred on any of the projects.
7. All of the mixtures were highly resistant to rutting, even those with binder contents of 10% placed in areas with hot climate conditions.
8. Reflective cracking observed was virtually all transverse cracking and primarily associated with environmental forces.

9. The primary effect of traffic loading on cracking was a reduction in percent and width of cracks in the wheel paths. For example median turn lanes and shoulders experienced higher incidence of cracking than the traffic lanes.
10. In areas of high traffic, reflective cracking was reduced.
11. Forces created by acceleration or deceleration of vehicles contribute to the occurence of reflective cracking. Approaches to areas with traffic signals clearly demonstrated the relationship of vehicle forces on the pavement.
12. Fatigue or load associated structural failure was virtually nonexistent in the AR overlay mixes.
13. In the few localized areas of fatigue or structural failure, the cracking was hairline in width without spalling and potholing and required no maintenance activities.
14. In incidences of reflective cracking on the ARAC mixes on the low volume roads, the cracking was clean. The crack edges were not spalling, curling or warping and the ride remained good to excellent, without crack sealing which not the case in adjacent pavements.
15. Aggregate materials used in all the mixtures were non-plastic and had no PI.

RECOMENDATIONS

1. Binder content of ARAC mixtures on low volume roads should be increased to avoid the incidence of oxidation.
2. Consider the use of softer asphalts particularly in light traffic and cooler climate conditions.
3. The ARAC projects should be cored and evaluate for aging with respect to binder grade and film thickness, void content and aggregate absorption.
4. Since reflective cracking in these overlays has been a function of environmental forces, ie; the stresses introduced by pavement contraction and/or warping/curling, a study of the direct tensile strengths and elastic relaxation of these materials might be very effective at developing rational design methods. The direct tensile strengths of these materials could be evaluated at variant temperatures, degree of aging, and binder contents. Since reflective cracking is the primary interest, the testing should be based on tensile strengths at low temperatures or on the moduli associated with aged materials. This aging characteristic probably could be duplicated by varying the test temperature.

REFFERENCES

TABLE OF FIGURES

FIGURE 1 Aggregate gradations for Gap and Open mixtures

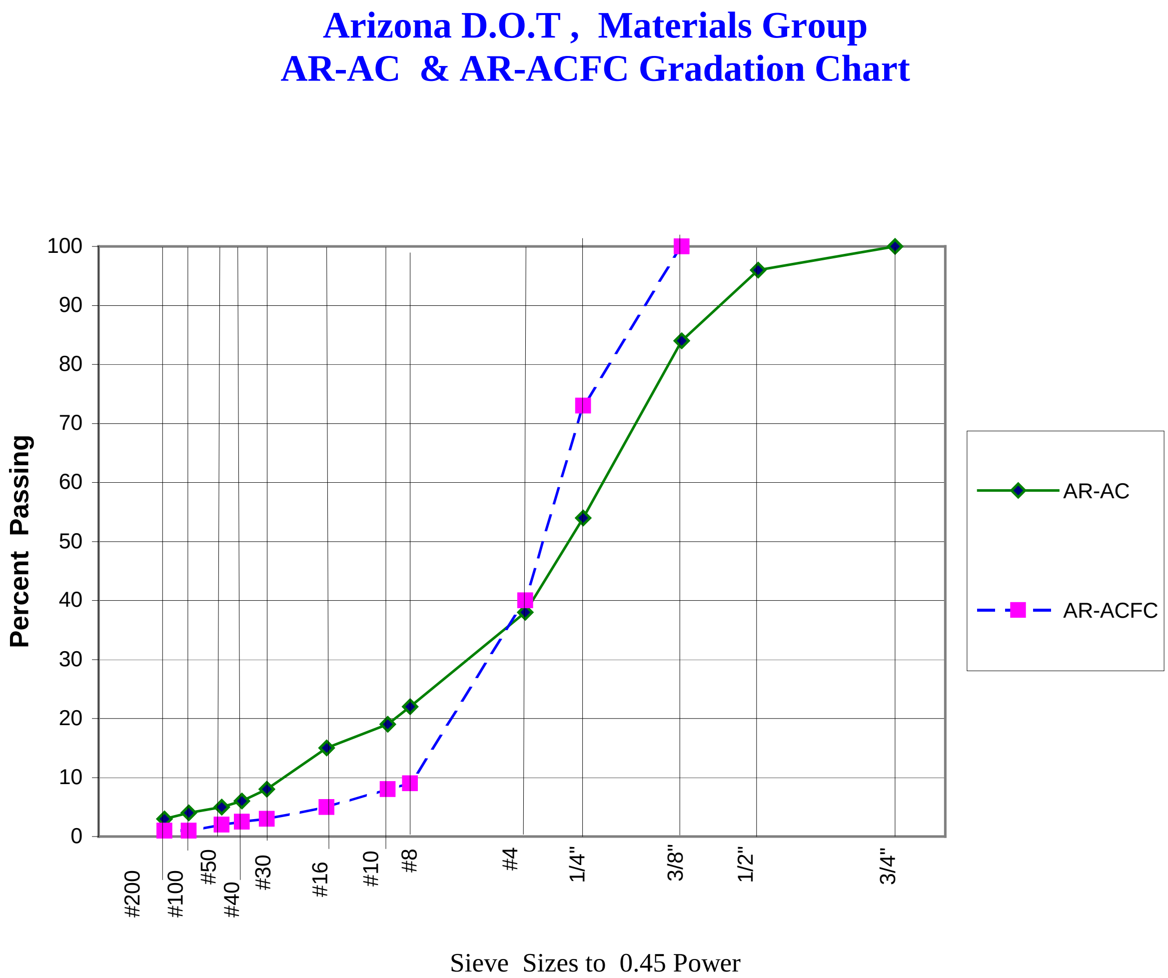


FIGURE 2 Interstate 19, Tucson South MP 58-60 constructed 1988

First three images from top to bottom and left to right are archive photographs from 1986, the third picture of crack sealing prior to overlay in 1988.

The last three photographs are typical of the joints reflecting through the overlay. The crack width is less than ¼ inch. In most cases the joints are still closed with the crack sealant "wicking" through the thin overlay. Photos taken in April 2000.

FIGURE 3 Interstate 19, Irvington Road – I-49 MP 60-64 constructed 1991

Top Row and Middle Left - PCCP before overlay. Middle Right – Typical pavement appearance after nine years. Bottom Left - The cracking above joints is typically less than ¼ inch, the cracks remain closed and have very little or no spalling with excellent rock retention. Bottom Right – An example of the worst case of cracking.

FIGURE 4 Interstate 17, Buckeye Rd. – Van Buren MP 198.2-199.8 constructed 1990

Above - Photos before overlay indicating patch work along joints and faulting. Below - photos taken in 2000, ten years of service, with very little cracking evident. Note the "pot hole" in the lower right photo probably due to failure of patching material. About five such "pot holes" are present in the North Bound lanes.

FIGURE 5 Interstate 40 Walnut Canyon MP 195.08 – 205.2 Overlay Constructed 1990

FIGURE 6 Interstate 40 Test Section Diagram

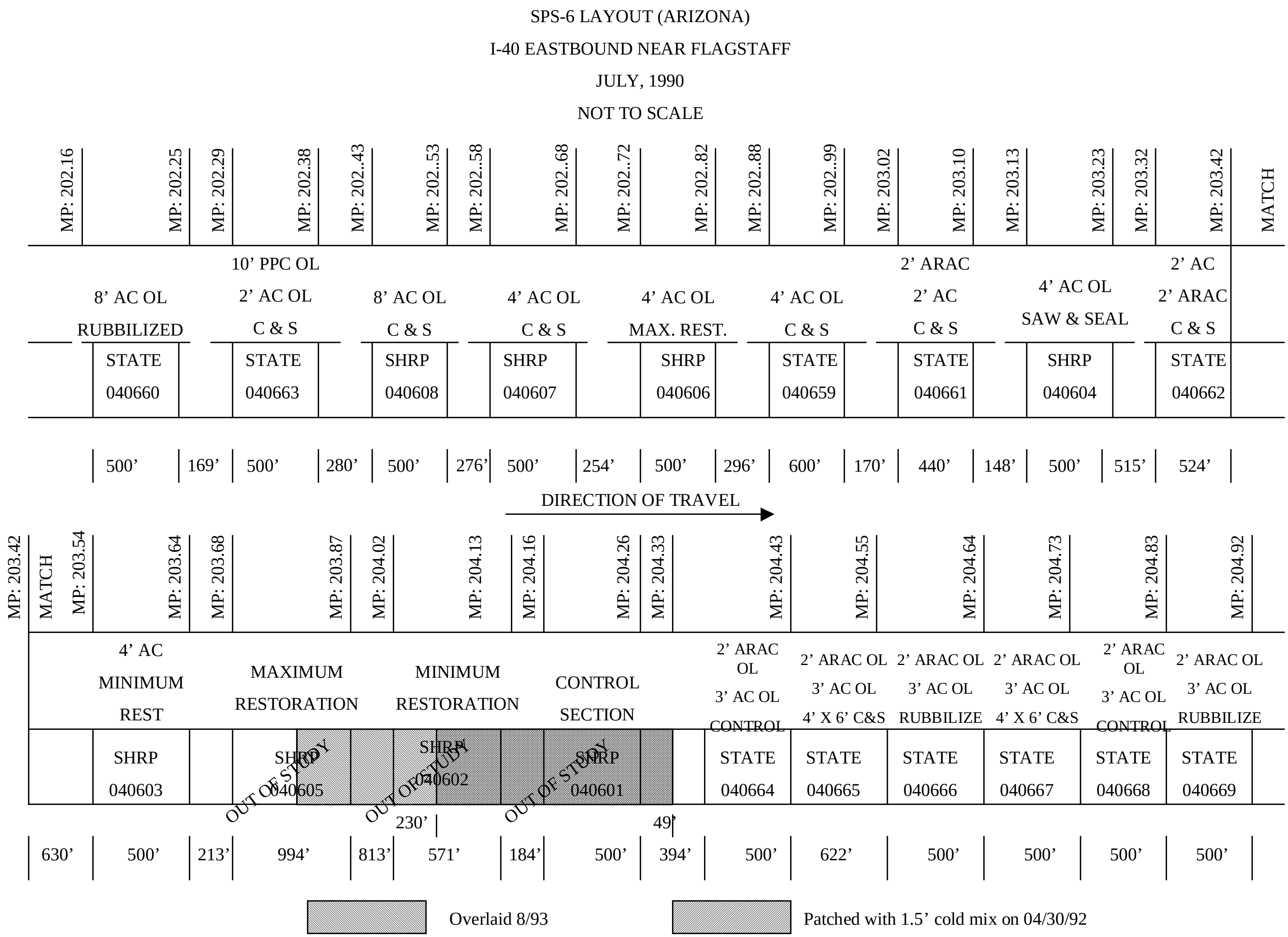


FIGURE 7 Interstate 40 Test Section Photographs

From left to right: State Test Section 040660 - 8 inch conventional AC overlay of rubbilized PCCP, SHRP Test Section 040607 – 4 inch AC overlay of cracked and seated PCCP

From left to right: State Test Section 040661 - 2 inch ARAC overlay and 2 inch AC leveling course on cracked and seated PCCP, SHRP Test Section 040604 – 4 inch AC overlay of saw and sealed joints in PCCP.

Left - Comparison photographs of Section 040659, 4" OL over Crack and Seat PCCP on left and Section 040661, 2" ARAC over 2" AC over Crack and Seat PCCP on right. The photographs were taken from a "cherry picker" sixty feet above the pavement surface in 1998, after eight years of performance.

FIGURE 8 Interstate 8, Aztec County Line MP 72-82, constructed 1990

Above – Conditions prior to overlay. Bottom Right – Typical pavement condition 2000. Bottom right - shoulder crack stopping at AR-ACFC)

FIGURE 9 SR 68, Bullhead City-Kingman, constructed 1991

Top - 1990 road condition. Bottom 5 photos indicate some cracking but no maintenance. Lower Right - worst case of distress, usually on grades.

FIGURE 10 Glendale, 51st Ave, Northern – Butler, constructed 1991

No photographs were available before 1991 construction. The first three photographs demonstrate transverse cracking patterns where the cracks are closed or nonexistent in the wheel paths. This cracking only appears near the intersections. No maintenance activities are evident. The photograph on the bottom right is typical of most of the project.

FIGURE 11 Glendale, Camelback Road, 43rd Ave. to 75th Ave, constructed in 1991

No photographs were available before 1991 construction. The three images on top are typical of most of the project with good crack resistance. One area of localized distress is noted, depicted in middle left photo. Middle right – good crack resistance around utility port. Bottom left - Transverse cracks are closed or nonexistent in the wheel paths.

FIGURE 12 SR 77, Ina Road – Canada Del Oro, MP 74.9-79.1, constructed 1990

Top – Roadway prior to overlay in 1990
Bottom Three Photos – Typical cracking patterns after ten years of service, non-continuous transverse cracking closed in the wheel paths.

FIGURE 13 SR 260 Lakeside – Pinetop, MP 351-354 constructed 1991

Top – Before construction Middle and Bottom Left – Year 2000 review typical project view. Middle Right – Some transverse cracking on Eastern end of project apx. 20 feet spacing, sealed by maintenance.

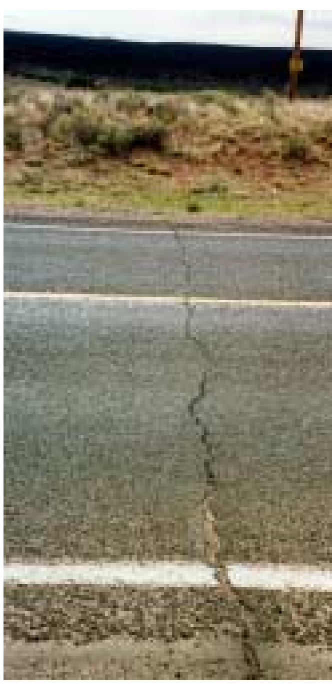
FIGURE 14 SR 160, Longhouse Valley MP 365.0-372.5 constructed 1988

Top – Typical road condition prior to overlay, 22% cracking. Below Right – Typical condition of overlay after 11 years. Below Middle – Localized area of fatigue near coal company terminal. Below Left – Transverse cracks spaced 50 feet apart, total project rated at 6% cracking.

FIGURE 15. SR 264, Route 77 to Pollaca Wash MP 384.8-392.3 constructed 1989

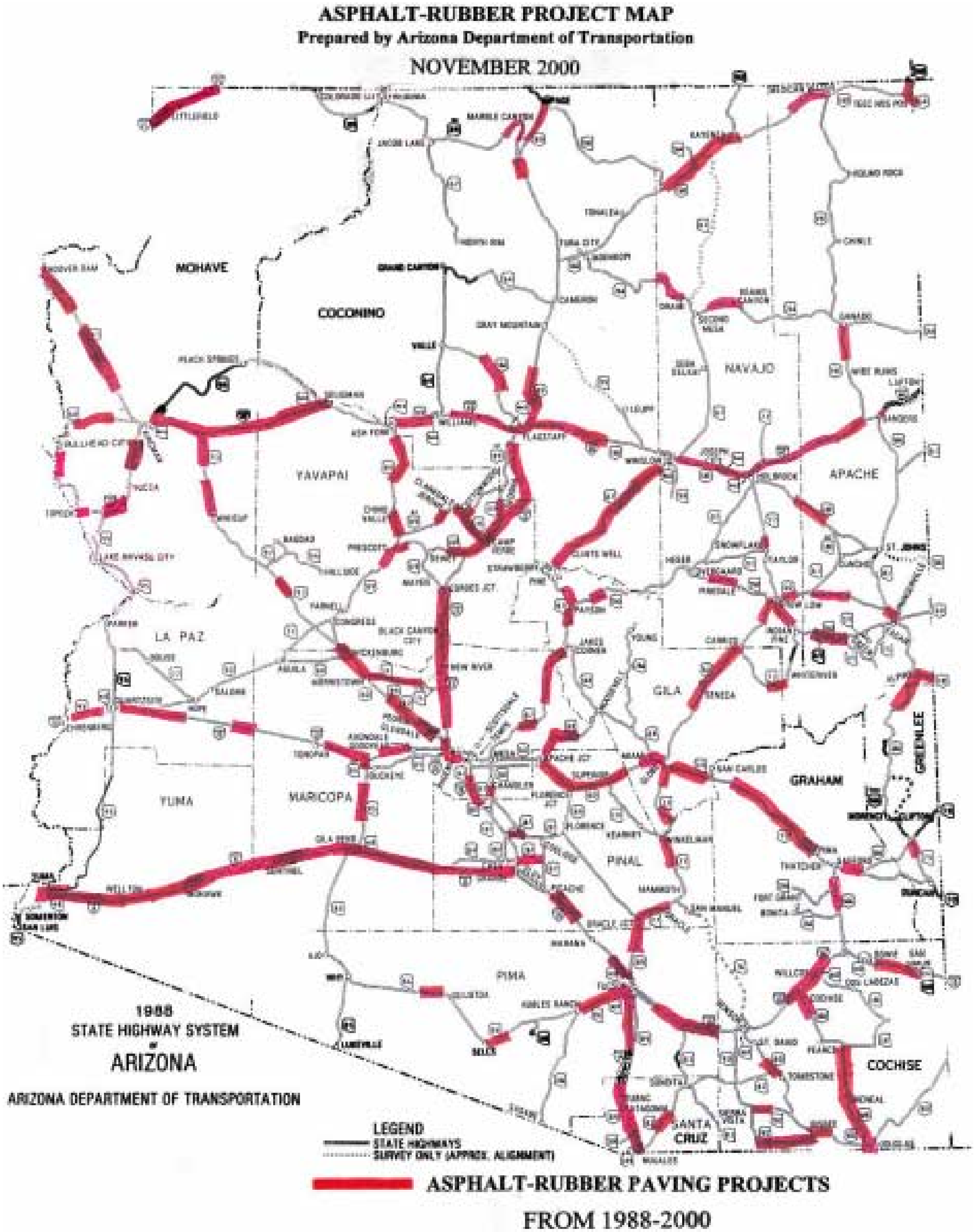
Far Right – Conditions prior to overlay in 1989, 10% cracking. Near Right – Transverse shrinkage cracks with 35 foot spacing, 7% cracking after 11 years. Below – Typical project views, rejuvenating agent applied in 1998 probably due to low binder content in overlay (6.5%)

FIGURE 16. SR 191, Klagetoh – Canado, MP 397-402.7, constructed 1991



Top – Project condition before overlay, 19 % cracking. Middle – Project condition 9 years after overlay. Below Right and Middle – Some cracking on grades, spaced 20 feet. Below – Typical crack closed in wheel paths, total project cracking 1%.

FIGURE 17. Arizona Asphalt Rubber Project Map 1988-2000



APPENDIX A ADOT A-R Specifications.

SECTION 1009 ASPHALT-RUBBER MATERIAL:

1009-1 Description:
The work under this section shall consist of furnishing, proportioning and mixing all the ingredients necessary to produce an asphalt-rubber material.

1009-2 Materials:

1009-2.01 Asphalt-Rubber:

(A) Asphalt Cement:

Asphalt cement shall be a performance grade (PG) asphalt binder conforming to the requirements of Section 1005.

(B) Rubber:

Rubber shall meet the following gradation requirements when tested in accordance with Arizona Test Method 714.

Sieve Size	Percent Passing	
	Type A	Type B
No. 8	100	
No. 10	95 - 100	100
No. 16	0 - 10	65 - 100
No. 30		20 - 100
No. 50		0 - 45
No. 200		0 - 5

The rubber shall have a specific gravity of 1.15 ± 0.05 and shall be free of wire or other contaminating materials, except that Type A rubber shall contain not more than 0.1 percent fabric and Type B shall contain not more than 0.5 percent fabric. Calcium carbonate, up to four percent by weight of the granulated rubber, may be added to prevent the particles from sticking together.

Certificates of Compliance conforming to Subsection 106.05 shall be submitted. In addition, the certificates shall confirm that the rubber is a crumb rubber, derived from processing whole scrap tires or shredded tire materials; and the tires from which the crumb rubber is produced are taken from automobiles, trucks, or other equipment owned and operated in the United States. The certificates shall also verify that the processing does not produce, as a waste product, casings or other round tire material that can hold water when stored or disposed of above ground.

1009-2.02 Asphalt-Rubber Proportions:

The asphalt-rubber shall contain a minimum of 20 percent ground rubber by the weight of the asphalt cement.

1009-2.03 Asphalt-Rubber Properties:

Asphalt-rubber shall conform to the following:

Property	Requirement		
	Type 1	Type 2	Type 3
Grade of base asphalt cement	PG 64-16	PG 58-22	PG 52-28
Rotational Viscosity*: 350 ^{o}F; pascal seconds	1.5 - 4.0	1.5 - 4.0	1.5 - 4.0

Property	Requirement		
	Type 1	Type 2	Type 3
Penetration: 39.2 ^{o}F, 200 g, 60 sec. (ASTM D 5); minimum	10	15	25
Softening Point: (ASTM D 36); ^{o}F, minimum	135	130	125
Resilience: 77 ^{o}F (ASTM D 5329); %, minimum	30	25	15
* The viscotester used must be correlated to a Rion (formerly Haake) Model VT-04 viscotester using the No. 1 Rotor. The Rion viscotester rotor, while in the off position, shall be completely immersed in the binder at a temperature from 350 to 355 degrees F for a minimum heat equilibrium period of 60 seconds, and the average viscosity determined from three separate constant readings (± 0.5 pascal seconds) taken within a 30 second time frame with the viscotester level during testing and turned off between readings. Continuous rotation of the rotor may cause thinning of the material immediately in contact with the rotor, resulting in erroneous results.			

1009-2.04 Asphalt-Rubber Design:

At least two weeks prior to the use of asphalt-rubber, the contractor shall submit an asphalt-rubber design prepared by an approved laboratory. Such design shall meet the requirements specified herein. The design shall show the values obtained from the required tests, along with the following information: percent, grade and source of the asphalt cement used; and percent, gradation and source(s) of rubber used.

1009-3 Construction Requirements:

During production of asphalt-rubber, the contractor shall combine materials in conformance with the asphalt-rubber design unless otherwise approved by the Engineer.

1009-3.01 Mixing of Asphalt-Rubber:

The temperature of the asphalt-cement shall be between 350 and 400 degrees F at the time of addition of the ground rubber. No agglomerations of rubber particles in excess of two inches in the least dimension shall be allowed in the mixing chamber. The ground rubber and asphalt-cement shall be accurately proportioned in accordance with the design and thoroughly mixed prior to the beginning of the one-hour reaction period. The contractor shall document that the proportions are accurate and that the rubber has been uniformly incorporated into the mixture. Additionally, the contractor shall demonstrate that the rubber particles have been thoroughly mixed such that they have been "wetted." The occurrence of rubber floating on the surface or agglomerations of rubber particles shall be evidence of insufficient mixing. The temperature of the asphalt-rubber immediately after mixing shall be between 325 and 375 degrees F. The asphalt-rubber shall be maintained at such temperature for one hour before being used.

Prior to use, the viscosity of the asphalt-rubber shall be tested by the use of a rotational viscotester, which is to be furnished by the contractor or supplier.

1009-3.02 Handling of Asphalt-Rubber:

Once the asphalt-rubber has been mixed, it shall be kept thoroughly agitated during periods of use to prevent settling of the rubber particles. During the production of asphaltic concrete the temperature of the asphalt-rubber shall be maintained between 325 and 375 degrees F. However, in no case shall the asphalt-rubber be held at a temperature of 325 degrees F or above for more than 10 hours. Asphalt-rubber held for more than 10 hours shall be allowed to cool and gradually reheated to a temperature between 325 and 375 degrees F before use. The cooling and reheating shall not be allowed more than one time. Asphalt-rubber shall not be held at temperatures above 250 degrees F for more than four days.

For each load or batch of asphalt-rubber, the contractor shall provide the Engineer with the following documentation:

(1) The source, grade, amount and temperature of the asphalt cement prior to the addition of rubber.

(2) The source and amount of rubber and the rubber content expressed as percent by the weight of the asphalt cement.

(3) Times and dates of the rubber additions and resultant viscosity test.

(4) A record of the temperature, with time and date reference for each load or batch. The record shall begin at the time of the addition of rubber and continue until the load or batch is completely used. Readings and recordings shall be made at every temperature change in excess of 20 degrees F, and as needed to document other events which are significant to batch use and quality.

SECTION 413 ASPHALTIC CONCRETE (ASPHALT-RUBBER):

413-1 Description:

Asphaltic Concrete (Asphalt-Rubber), hereinafter asphaltic concrete, shall consist of furnishing all materials, mixing at a plant, hauling, and placing a mixture of aggregate materials, mineral admixture, and bituminous material (asphalt-rubber) to form a pavement course or to be used for other specified purposes, in accordance with the details shown on the project plans and the requirements of these specifications, and as directed by the Engineer.

The contractor shall be responsible for all adjustments to its equipment necessary to properly accommodate the use of asphalt-rubber as a bituminous material.

413-2 Asphaltic Concrete Mix Design Criteria:

Mix designs will be performed in accordance with Arizona Test Method 815, modified as necessary for Asphaltic Concrete (Asphalt-Rubber). Mix designs shall meet the criteria in Table 413-1.

TABLE 413-1
ASPHALTIC CONCRETE MIX DESIGN CRITERIA

Criteria	Requirement
1. Effective Voids: %, Range	5.5 ± 1.0
2. Voids in Mineral Aggregate: %, Min.	19.0
3. Absorbed Asphalt-Rubber: %, Range	0 - 1.0

413-3 Materials:

413-3.01 Mineral Aggregate Source:

There is no Department-furnished source of mineral aggregate. The contractor shall provide a source in accordance with the requirements of Section 1001 of these specifications.

When the contractor selects a source or sources, it shall notify the Engineer. The contractor shall be solely responsible for assuring that the mineral aggregate meets all requirements and, when processed, is fully capable of providing asphaltic concrete which meets all the requirements of these specifications.

413-3.02 Mineral Aggregate:

Coarse and intermediate mineral aggregate shall consist of crushed gravel, crushed rock, or other approved inert materials with similar characteristics, or a combination thereof, conforming to the requirements of these specifications.

Fine mineral aggregate shall be obtained from crushed gravel or crushed rock. All uncrushed material passing a No. 4 sieve shall be removed prior to the crushing, screening, and washing operations necessary to produce the specified gradation. The contractor shall notify the Engineer a minimum of 48 hours in advance of crushing the material to be used as mineral aggregate, so all crushing operations are inspected. Existing stockpile material which has not been inspected during crushing will not be permitted for use unless the contractor is able to document to the Engineer's satisfaction that the mineral aggregate has been crushed. Any material inspected by the Department as crushed material shall be separated from the contractors other stockpiles and reserved for use by the Department.

Mineral aggregate shall be separated into stockpiles by the contractor. No individual stockpile usage shall be less than three percent of the total mineral aggregate. No individual stockpile shall be permitted to contain more than 6.0 percent passing the No. 200 sieve when tested in accordance with Arizona Test Method 201. If necessary, the contractor shall wash the mineral aggregate to meet this requirement.

Mineral aggregate furnished for mix designs shall be representative of the source(s), and sampled from the materials stockpiles to be utilized in asphaltic concrete production. Mix designs shall be performed utilizing mineral aggregate which conforms to the grading limits in Table 413-2.

TABLE 413-2
MIX DESIGN GRADING LIMITS FOR MINERAL AGGREGATE
(WITHOUT ADMIXTURE)

Sieve Size	Percent Passing
3/4 Inch	100
1/2 Inch	80 - 100
3/8 Inch	65 - 80
No. 4	28 - 42
No. 8	14 - 22
No. 200	0 - 2.5

Mineral aggregate shall conform to the requirements in Table 413-3 when tested in accordance with the applicable test methods.

Tests on aggregates outlined in Table 413-3, other than abrasion, shall be performed on materials furnished for mix design purposes and composited to the mix design gradation. Abrasion shall be performed separately on samples from each source of mineral aggregate. All sources shall meet the requirements for abrasion.

TABLE 413-3
MINERAL AGGREGATE CHARACTERISTICS

Characteristics	Test Method	Requirement
Combined Bulk Specific Gravity	Arizona Test Method 815	2.35 - 2.85
Combined Water Absorption	Arizona Test Method 815	0 - 2.5%
Sand Equivalent	AASHTO T 176	Minimum 55
Fractured Coarse Aggregate Particles	Arizona Test Method 212	Minimum 85% (two Fractured Faces determined on plus No. 4 material)
Abrasion	AASHTO T 96	100 Rev., Max 9%

TABLE 413-3 MINERAL AGGREGATE CHARACTERISTICS		
Characteristics	**Test Method**	**Requirement**
		500 Rev., Max 40%

413-3.03 Mineral Admixture:

Mineral admixture will be required. The amount shall be 1.0 percent, by weight of the mineral aggregate, and shall be either Portland Cement type II or hydrated lime, conforming to the requirements of Table 413-4.

TABLE 413-4 MINERAL ADMIXTURE	
Material	**Requirement**
Portland Cement, Type II	ASTM C 150
Hydrated Lime	ASTM C 1097

A Certificate of Analysis conforming to the requirements of Subsection 106.05 shall be submitted to the Engineer.

413-3.04 Bituminous Material:

Bituminous material shall be asphalt-rubber conforming to the requirements of Section 1009 of the specifications. The type of asphalt-rubber shall be as shown in the Special Provisions. The crumb rubber gradation shall be Type B conforming to the requirements of Section 1009.

In no case shall the asphalt-rubber be diluted with extender oil, kerosene, or other solvents. Any asphalt-rubber so contaminated shall be rejected.

Any kerosene or other solvents used in the cleaning of equipment shall be purged from the system prior to any subsequent use of that equipment.

413-3.05 Blotter Material:

An application of blotter material may be required following the placement of the asphaltic concrete and prior to opening the roadway to traffic. The blotter material shall conform to the requirements of Section 404. The blotter material shall be applied in one or more applications for a total application of two pounds per square yard. The Engineer may reduce or eliminate blotter material if deemed to be unnecessary.

413-4 Mix Design:

Approximately 300 pounds of produced mineral aggregate, in proportion to the anticipated percent usage, shall be obtained by the contractor and witnessed by the Engineer so that both parties are satisfied that samples are representative of the mineral aggregate to be utilized in the asphaltic concrete production.

The contractor shall also furnish representative samples of the following materials: a five-pound sample of the crumb rubber proposed for use, one gallon of asphalt cement from the intended supplier, three gallons of the proposed mixture of asphalt and rubber, and a one-gallon can of the mineral admixture to be used in the asphaltic concrete.

Along with the samples furnished for mix design testing, the contractor shall submit a letter explaining in detail its methods of producing mineral aggregate including wasting, washing, blending, proportioning, etc., and any special or limiting conditions it may propose. The contractor’s letter shall also state the source(s) of mineral aggregate, the source of asphalt cement and crumb rubber, the asphalt-rubber supplier, and the source and type of mineral admixture.

Within 10 working days of receipt of all samples and the contractor's letter in the Central Laboratory, the Department will provide the contractor with the percentage of asphalt-rubber to be used in the mix, the percentage to be used from each of the stockpiles of mineral aggregate, the composite mineral aggregate gradation, the composite mineral aggregate and mineral admixture gradation, and any special or limiting conditions for the use of the mix.

The Department will provide the contractor with material to be used for calibration of nuclear asphalt content gauges. The material will be fabricated by the Department utilizing asphalt-rubber submitted by the contractor for mix design purposes.

413-5 Mix Design Revisions:

The contractor shall not change its methods of crushing, screening, washing or stockpiling from those used during production of material used for mix design purposes without approval of the Engineer, or without requesting a new mix design.

During production of asphaltic concrete, the contractor, on the basis of field test results, may request a change to the approved mix design. The Engineer will evaluate the proposed changes and notify the contractor of the Engineer’s decision within two working days of the receipt of the request.

If, at any time, unapproved changes are made in the source of bituminous material, source(s) of mineral aggregate, production procedures, or proportional changes in violation of approved mix design stipulations, production shall cease until a new mix design is developed, or the contractor complies with the approved mix design.

At any time after the mix design has been approved, the contractor may request a new mix design.

The costs associated with the testing of materials in the developing of mix designs after a mix design acceptable to the Department has been developed shall be borne by the contractor.

If, during production, the Engineer on the basis of testing determines that a change in the mix design is necessary, the Engineer will issue a revised mix design. Should these changes require revisions to the contractor's operations which result in additional cost to the contractor, the contractor will be reimbursed for these costs. However, the Engineer reserves the right to modify the asphalt-rubber content without compensation being made to the contractor involving additional operation costs.

413-6 Acceptance of Materials:

413-6.01 General:

If the production of asphaltic concrete is stopped either for failure to meet the requirements specified hereinafter under Subsection 413-6.03, or because changes are made in the mix design, samples will be taken for calculating new consecutive averages either after production resumes or after the changes in the mix design have been made. The acceptance of the mineral aggregate gradation and the bituminous material content will be determined on the basis of the tests as hereinafter specified under Subsection 413-6.03. The Engineer reserves the right to increase the frequency of sampling and testing upon the resumption of asphaltic concrete production.

413-6.02 Mineral Aggregate:

Aggregate shall be free of deleterious materials, clay balls, and adhering films or other materials that prevent thorough coating of the aggregate with the bituminous material.

During asphaltic concrete production, the Engineer shall obtain and test samples of mineral aggregate for the determination of the sand equivalent and fractured coarse aggregate particles. The sample shall be obtained either from the cold feed prior to addition of mineral admixture, or from the stockpiles. Should such testing indicate results not meeting the requirements outlined in table 413-3 for sand equivalent and fractured coarse aggregate particles, operations shall cease and the contractor shall have the option of requesting a new mix design or correcting deficiencies in the aggregate stockpiles.

413-6.03 Asphaltic Concrete:

(A) Mineral Aggregate Gradation:

For each approximate 500 tons of asphaltic concrete, at least one sample of mineral aggregate will be taken. Samples will be taken in accordance with the requirements of Arizona Test Method 105 on a random basis just prior to the addition of mineral admixture and bituminous material by means of a sampling device which is capable of producing samples which are representative of the mineral aggregate. The device, which shall be approved by the Engineer, shall be furnished by the contractor. In any shift that the production of asphaltic concrete is less than 500 tons, at least one sample will be taken.

Samples will be tested for conformance with the mix design gradation without mineral admixture in accordance with the requirements of Arizona Test Method 201.

The gradation of the mineral aggregate will be considered to be acceptable unless the average of any three consecutive tests or the result of any single test varies from the mix design gradation percentages as follows:

Passing Sieve	Number of Tests	
	3 Consecutive	One
3/8 Inch and larger	± 4	± 6
No. 4	± 4	± 6
No. 8	± 3	± 5
No. 200	± 1.0	± 1.5

One hundred percent of the material shall pass the largest sieve size shown in Table 413-2.

At any time that test results indicate that the gradation of the mineral aggregate does not fall within all of the limits indicated, the production of asphaltic concrete shall cease immediately and shall not begin again until a calibration test indicates that the gradation is within the 3-consecutive test limits indicated.

(B) Asphalt-Rubber Content:

During production of asphaltic concrete, the contractor shall maintain at the plant site a nuclear asphalt content gauge calibrated and operated in accordance with Arizona Test Method 421. The calibration shall be performed using material supplied by the Department as stated in Section 413-4. Under the observation of the Engineer, the contractor shall determine the asphalt-rubber content by means of the nuclear asphalt content gauge a minimum of four times per full shift. The contractor’s technicians performing the testing, including the calibration of the nuclear gauge, shall meet the technician requirements given in the Department’s System for the Evaluation of Testing Laboratories. The requirements may be obtained from ADOT Materials Group, 1221 North 21st Avenue, Phoenix, AZ 85009-3740. Production of asphaltic concrete shall cease immediately and the plant and/or the nuclear asphalt content gauges re-calibrated if the Engineer determines the percent of asphalt-rubber has varied by an amount greater than ± 0.5 percent from the amount directed by the Engineer.

413-7 Construction Requirements:

413-7.01 Quality Control:

Quality control of mineral aggregate production and asphaltic concrete production shall be the responsibility of the contractor. The contractor shall perform sufficient testing to assure that mineral aggregate and asphaltic concrete are produced which meet all specified requirements. The Engineer reserves the right to obtain samples of any portion of any material at any point of the operations for the Engineer's own use.

413-7.02 Stockpiling:

The contractor will not be allowed to feed the hot plant from stockpiles containing less than two full days of production unless only two days production remain to be done or special conditions exist where the Engineer deems this requirement waived.

Mineral aggregate shall be separated and stockpiled so that segregation is minimized. An approved divider of sufficient size to prevent intermingling of stockpiles shall be provided.

413-7.03 Proportioning:

The contractor shall provide documentation by calibration charts or other approved means that the mineral aggregate, asphalt-rubber, and mineral admixture are being proportioned in accordance with the approved mix design.

Unless approved by the Engineer, no individual stockpile usage shall be less than three percent of the total mineral aggregate.

Changes in stockpile/hot bin use in excess of five percent from the approved mix design will not be permitted without the approval of the Engineer.

Mineral admixture shall be mechanically mixed with the mineral aggregate prior to combining the mineral aggregate and asphalt-rubber. The engineer may direct a spray of water be applied either to control the loss of the mineral admixture or to comply with any mix design requirements for wet mixing of the aggregate and admixture.

If a drum mix plant is used, the mineral admixture shall be added and thoroughly mixed by means of a mechanical mixing device prior to the mixture entering the drum drier. The mineral admixture shall be weighed across a weigh belt or an approved alternative weighing system, with a weight totalizer prior to entry into the mechanical mixing device. The mechanical mixing device shall be a pugmill type mixer consisting of at least two motorized shafts with mixing paddles. The mixing device shall be designed such that the mixture of aggregate and admixture is moved in a near horizontal direction by the mixing paddles without the aid of conveyor belts for a distance of at least three feet. Mixing devices which permit the mixture of aggregate and admixture to fall through mixing blades onto a belt or chute are not acceptable. The mixing device’s rated capacity in tons per hour shall not be exceeded by the rate of material feed to the mixer. The mixer shall be constructed to prevent the leakage of the contents. The mixer shall be located in the system at a location where the mixed material can be readily inspected on a belt prior to entry into the drum. The mixing device shall be capable of effective mixing in the full range of asphaltic concrete production rates.

A positive signal system and a limit switch device shall be installed in the plant at the point of introduction of the admixture. The positive signal system shall be placed between the metering device and the drum drier, and utilized during production whereby the mixing shall automatically be stopped if the admixture is not being introduced into the mixture.

If a batch plant is used, the mineral admixture shall be added and thoroughly mixed in the pugmill prior to adding asphalt-rubber.

The contractor shall furnish daily documentation to the Engineer that the required amount of mineral admixture has been incorporated into the asphaltic concrete.

No fine material which has been collected in the dust collection system shall be returned to the mixture unless the Engineer, on the basis of tests, determines that all or a portion of the collected fines can be utilized. If the Engineer so determines, the Engineer will authorize in writing the utilization of a specific proportion of the fines; however, authorization will not be granted unless the collected fines are uniformly metered into the mixture.

Mineral aggregate, mineral admixture, and asphalt-rubber shall be proportioned by volume, by weight, or by a combination of volume and weight.

When mineral aggregate, mineral admixture, and asphalt-rubber are proportioned by weight, all boxes, hoppers, buckets, or similar receptacles used for weighing materials, together with scales of any kind used in batching materials, shall be insulated against the vibration or movement of the rest of the plant due to the operation of any equipment so that the error in weighing with the entire plant operating shall not exceed two percent for any setting nor one and one half percent for any batch. Bituminous material shall be weighed in a heated, insulated bucket suspended from a springless dial scale system.

When mineral aggregate, mineral admixture, and asphalt-rubber are proportioned by volume, the correct portion of each mineral aggregate size introduced into the mixture shall be drawn from the storage bins by an approved type of continuous feeder which will supply the correct amount of mineral aggregate in proportion to the bituminous material and so arranged that the proportion of each mineral aggregate size can be separately adjusted. The continuous feeder for the mineral aggregate shall be mechanically or electrically actuated.

The introduction of asphalt-rubber shall be controlled by an automated system fully integrated with the controls for mineral aggregate and mineral admixture.

413-7.04 Drying and Heating:

A recording pyrometer or other approved recording thermometric instrument sensitive to a rate of temperature change not less than 10 degrees F per minute shall be so placed at the discharge chute of the drier in order to record automatically the temperature of the asphaltic concrete or mineral aggregate. A copy of the recording shall be given to the Engineer at the end of each shift.

The moisture content of the asphaltic concrete shall not exceed 0.5 percent. The moisture content will be determined in accordance with Arizona Test Method 406. Drying and heating shall be accomplished in such a manner as to preclude the mineral aggregate from becoming coated with fuel oil or carbon.

413-7.05 Mixing:

The production of the plant shall be governed by the rate required to obtain a thorough and uniform mixture of the materials.

A positive signal system shall be provided to indicate the low level of mineral aggregate in the bins. The plant will not be permitted to operate unless this signal system is in good working condition. Each bin shall have an overflow chute or a divider to prevent material from spilling into adjacent bins.

The temperature of asphaltic concrete upon discharge from the mixer shall not exceed 350 degrees F. If the asphaltic concrete is discharged from the mixer into a hopper, the hopper shall be constructed so that segregation of the asphaltic concrete will be minimized.

413-7.06 Placing and Finishing:

(A) General Requirements:

The handling of asphaltic concrete shall at all times be such as to minimize segregation. Any asphaltic concrete which displays segregation shall be removed and replaced.

Before asphaltic concrete is placed, the surface to be paved shall be cleaned of all objectionable material and tacked with asphalt cement in accordance with the requirements of Section 404 of the specifications. The cleaning of the surface, the tacking of the surface, and the amount and grade of asphalt cement used shall be as directed by and acceptable to the Engineer.

A light coat of asphalt cement shall be applied as directed to edges or vertical surfaces against which asphaltic concrete is to be placed.

The base or subgrade upon which the asphaltic concrete is to be placed shall be prepared in accordance with the applicable requirement for the material involved and maintained in a smooth and firm condition until placement. Asphaltic concrete shall not be placed on a frozen or excessively wet base or subgrade.

Asphaltic concrete shall be placed only when the temperature of the surface on which the asphaltic concrete is to be placed is at least 65 degrees F and the ambient temperature is at least 65 degrees F and rising. The placement shall be stopped when the ambient temperature is at or below 70 degrees F and falling.

At any time the Engineer may require that the work cease or that the work day be reduced in the event of weather conditions which would have an adverse effect upon the asphaltic concrete.

All asphaltic concrete shall be placed either as a leveling course or as a surfacing course. Leveling courses are defined as courses placed for the primary purpose of raising an existing paved or unpaved surface to a smooth plane. Surfacing courses are defined as courses placed to serve either as the traffic surface or as a surface upon which a finishing course or seal coat is to be placed.

Thickness of leveling and surfacing courses will be shown on the project plans. No change in thickness will be allowed without the written approval of the Engineer.

(B) Loading Asphaltic Concrete into the Paving Machine:

If the asphaltic concrete is dumped directly into the paving machine from the hauling trucks, care shall be taken to avoid jarring the machine or moving it out of alignment. No vertical load shall be exerted on the paving machine by the trucks. Trucks, while dumping, shall be securely attached to the paving machine.

If the asphaltic concrete is dumped upon the surface being paved and subsequently loaded into the paving machine, the loading equipment shall be self-supporting and shall not exert any vertical load on the paving machine. Substantially all of the asphaltic concrete shall be picked up and loaded into the paving machine.

(C) Placing and Finishing Asphaltic Concrete by Means of Self-Propelled Paving Machines:

All courses of asphaltic concrete shall be placed and finished by means of self-propelled paving machines except under certain conditions or at certain locations where the Engineer deems the use of self-propelled paving machines impractical.

In order to achieve, as far as practical, a continuous operation, the speed of the paving machine shall be coordinated with the production of the plant. If the paving machine is stopped for more than three minutes, or there is a three minute or longer interval between the completion of delivery by one truck and the beginning of delivery by the next truck, the paving machine shall be pulled away from the mat in order for the rollers to compact this area in accordance with the temperature limitations given hereinafter under Subsection 413-7.08(C). A transverse construction joint shall be made by a method approved by the Engineer.

Self-propelled paving machines shall spread the mixture without segregation or tearing within the specified tolerances, true to the line, grade, and crown indicated on the project plans. Pavers shall be equipped with hoppers and augers which will distribute the mixture uniformly in front of adjustable screeds.

Screeds shall include any strike-off device operated by tamping or vibrating action which is effective without tearing, shoving or gouging the mixture and which produces a course with a uniform texture and density for the full width being paved. Screeds shall be adjustable as to height and crown and shall be equipped with a controlled heating device for use when required.

Tapered sections not exceeding eight feet in width, or widened sections not exceeding four feet in width may be placed and finished by other means approved by the Engineer.

(D) Automatically Actuated Control System:

Except under certain conditions or at certain locations where the Engineer deems the use of automatic controls impractical, all courses of asphaltic concrete shall be placed and finished by means of self-propelled paving machines equipped with an automatically actuated control system.

The control system shall control the elevation of the screed at each end by controlling the elevation of one end directly and the other end indirectly either through controlling the transverse slope or alternately when directed, by controlling the elevation of each end independently.

The control system shall be capable of working with the following devices which shall be furnished with the machine:

Ski-type device at least 30 feet in length, supported throughout its entire length.

Short ski.

500 feet of control line and stakes.

Joint matcher shoe.

The control line shall be set and maintained taut by the contractor to the grade and alignment established by the Engineer.

Failure of the control system to function properly shall be cause for the suspension of the asphaltic concrete operations.

413-7.07 Joints:

Longitudinal joints of each course shall be staggered a minimum of one foot with relation to the longitudinal joint of the immediate underlying course.

The contractor shall schedule its paving operations to minimize exposed longitudinal edges. Unless otherwise approved by the Engineer, the contractor shall limit the placement of asphaltic concrete courses, in advance of adjacent courses, to one shift of asphaltic concrete production. The contractor shall schedule its paving operations in such a manner to eliminate exposed longitudinal edges over weekends or holidays.

Longitudinal joints shall be located within one foot of the center of a lane or within one foot of the centerline between two adjacent lanes. Joints shall be formed by a slope shoe or hot lapped, and shall be compacted while the mixture is still hot.

Before a surface course is placed in contact with a cold transverse construction joint, the cold existing asphaltic concrete shall be trimmed to a vertical face by cutting the existing asphaltic concrete back for its full depth and exposing a fresh face. After placement and finishing of the new asphaltic concrete, both sides of the joint shall be dense and the joint shall be well sealed. The surface in the area of the joint shall conform to the requirements hereinafter specified for surface tolerances when tested with the straightedge placed across the joint.

When surfacing courses are placed on ten-foot or wider shoulders that are to receive a rumble strip, any longitudinal joint between the shoulder and the travel lane shall be located at the travel lane edge of the rumble strip.

413-7.08 Compaction:

(A) General Requirements:

The temperature of asphaltic concrete just prior to compaction shall be at least 275 ^{o}F.

The wheels of compactors shall be wetted with water, or if necessary soapy water, or a product approved by the Engineer to prevent the asphaltic concrete from sticking to the steel wheels during rolling. The Engineer may change the rolling procedure if in the Engineer's judgment the change is necessary to prevent picking up of the asphaltic concrete.

(B) Equipment:

For courses greater than one inch in nominal thickness, a minimum of one static steel-wheel compactor and two vibratory steel-wheel compactors shall be provided; however, sufficient vibratory steel-wheel compactors shall be provided to cover the entire width of the paving machine on the initial forward pass.

For courses of one inch or less in nominal thickness, a minimum of three static steel-wheel compactors shall be provided; however, sufficient compactors must be provided to cover the entire width of the paving machine on the initial forward pass while a static compactor remains to complete final rolling. If the asphaltic concrete production rate exceeds 250 tons per hour, an additional static steel-wheel compactor shall be provided.

The compactors shall weigh not less than eight tons.

The compactors shall be self-propelled and shall be operated with the drive wheel in the forward position. Vibratory rollers shall be used in the mode required by the Engineer. Vibratory compactors shall not be used in the vibratory mode for courses of one inch or less in nominal thickness.

(C) Rolling Procedure:

Vibratory compactors shall be used for initial breakdown on courses greater than one inch in nominal thickness. Static steel wheel compactors, or vibratory compactors in the static mode, shall be used for initial breakdown on courses one inch or less in nominal thickness. Initial breakdown rollers shall be maintained no more than 300 feet behind the paving machine. The roller(s) for final compaction shall follow as closely behind the initial breakdown as possible. As many passes as are possible shall be made with the compactors before the temperature of the asphaltic concrete falls below 220 ^{o}F.

All edges shall be compacted by methods approved by the Engineer, while the mixture is still hot.

413-7.09 Surface Requirements and Tolerances:

All courses of asphaltic concrete shall be compacted as required, smooth and reasonably true to the required lines, grades, and dimensions.

Leveling course surfaces shall not vary more than 1/4 inch from the lower edge of a 10-foot straightedge when the straightedge is placed parallel to the center line of the roadway.

Surfacing course surfaces shall not vary more than 1/8 inch from the lower edge of a ten-foot straightedge when the straightedge is placed parallel to the center line of the roadway, or 1/4 inch when placed in the transverse direction across longitudinal joints.

413-7.10 Acceptance:

Asphaltic concrete will be accepted complete in place, if, in the judgment of the Engineer, the asphaltic concrete reasonably conforms to the requirements specified herein. Asphaltic concrete that is not acceptable and is rejected shall be replaced to the satisfaction of the Engineer and at no expense to the Department.

413-8 Method of Measurement:

Asphaltic concrete will be measured by the ton for the mixture actually used, which will include the weight of mineral aggregate, mineral admixture, and asphalt-rubber. Measurement will include any weight used in construction of intersections, turnouts, or other miscellaneous items or surfaces.

Asphalt-rubber material will be measured by the ton.

The weight of the asphalt-rubber material shall either be determined by weighing directly enroute from the reaction vessel to the point of delivery or be determined from the weight of the asphalt cement and the weight of the rubber minus wastage.

Mineral admixture will be measured by the ton.

413-9 Basis of Payment:

The accepted quantities of asphaltic concrete, measured as provided above, will be paid for at the contract unit price per ton, which price shall be full compensation for the work, complete in place, as specified herein.

Payment for the asphalt-rubber will be made by the ton, including asphalt cement and crumb rubber. The results of a nuclear asphalt content gauge shall not be used to determine the weight of asphalt-rubber material as the basis of payment.

Payment for mineral admixture will be made by the ton.

SECTION 414 ASPHALTIC CONCRETE FRICTION COURSE (ASPHALT-RUBBER):

414-1 Description:

Asphaltic Concrete Friction Course (Asphalt-Rubber), hereinafter asphaltic concrete, shall consist of furnishing all materials, mixing at a plant, hauling, and placing a mixture of aggregate materials, mineral admixture, and bituminous material (asphalt-rubber) to form a pavement course or to be used for other specified purposes, in accordance with the details shown on the project plans and the requirements of these specifications, and as directed by the Engineer.

The contractor shall be responsible for all adjustments to its equipment necessary to properly accommodate the use of asphalt-rubber as a bituminous material.

414-2 Asphaltic Concrete Mix Design Criteria:

Mix designs will be performed in accordance with Arizona Test Method 814, modified as necessary for Asphaltic Concrete Friction Course (Asphalt-Rubber). The allowable range of percent absorbed asphalt-rubber shall be 0-1.0, when tested in accordance with the applicable section of Arizona Test Method 815.

414-3 Materials:

414-3.01 Mineral Aggregate Source:

There is no Department-furnished source of mineral aggregate. The contractor shall provide a source in accordance with the requirements of Section 1001 of these specifications.

When the contractor selects a source or sources, it shall notify the Engineer. The contractor shall be solely responsible for assuring that the mineral aggregate meets all requirements and, when processed, is fully capable of providing asphaltic concrete which meets all the requirements of these specifications.

414-3.02 Mineral Aggregate:

Mineral aggregate shall be separated into at least two stockpiles. No individual stockpile usage shall be less than three percent of the total mineral aggregate.

Coarse mineral aggregate shall consist of crushed gravel, crushed rock, or other approved inert materials with similar characteristics, or a combination thereof, conforming to the requirements of these specifications.

Fine mineral aggregate or blend material shall consist of natural sand, sand prepared from rock, or other approved inert materials, or a combination thereof, conforming to the requirements of these specifications.

Material aggregate furnished for mix designs shall be representative of the source(s) and sampled from the materials stockpiles to be utilized in asphaltic concrete production. Mix designs shall be performed utilizing mineral aggregate which conforms to the grading limits in Table 414-1.

TABLE 414-1
MIX DESIGN GRADING LIMITS FOR MINERAL AGGREGATE (Without Admixture)

Sieve Size	Percent Passing
3/4 Inch	100
No. 4	30 - 45
No. 8	4 - 8
No. 200	0 - 2.5

Mineral aggregate shall conform to the requirements in Table 414-2 when tested in accordance with the applicable test methods.

Tests on aggregates outlined in Table 414-2, other than abrasion, shall be performed on materials furnished for mix design purposes and composited to the mix design gradation. Abrasion shall be performed separately on samples from each source of mineral aggregate. All sources shall meet the requirements for abrasion.

TABLE 414-2
MINERAL AGGREGATE CHARACTERISTICS

Characteristic	Test Method	Requirement
Combined Bulk Specific Gravity	Arizona Test Method 814	2.35 - 2.85
Combined Water Absorption	Arizona Test Method 814	0 – 2.5%

TABLE 414-2 MINERAL AGGREGATE CHARACTERISTICS		
Characteristic	**Test Method**	**Requirement**
Sand Equivalent	Arizona Test Method 242	Minimum 55
Fractured Coarse Aggregate Particles	Arizona Test Method 212	Minimum 85% (two fractured faces)
Flakiness Index	Arizona Test Method 233	Maximum 25
Carbonates in Aggregate	Arizona Test Method 238	Maximum 30%
Abrasion	AASHTO T 96	100 Rev., Max. 9% 500 Rev., Max. 40%

414-3.03 Mineral Admixture:

Mineral admixture will be required. The amount shall be 1.0 percent, by weight of the mineral aggregate and shall be either portland cement type II or hydrated lime, conforming to the requirements of Table 414-3.

TABLE 414-3 MINERAL ADMIXTURE	
Material	**Requirement**
Portland Cement, Type II	ASTM C 150
Hydrated Lime	ASTM C 1097

A Certificate of Analysis conforming to the requirements of Subsection 106.05 shall be submitted to the Engineer.

414-3.04 Bituminous Material:

Bituminous material shall be asphalt-rubber conforming to the requirements of Section 1009 of the specifications. The type of asphalt-rubber shall be as shown in the Special Provisions. The crumb rubber gradation shall be Type B conforming to the requirements of Section 1009.

In no case shall the asphalt-rubber be diluted with extender oil, kerosene, or other solvents. Any asphalt-rubber so contaminated shall be rejected.

Any kerosene or other solvents used in the cleaning of equipment shall be purged from the system prior to any subsequent use of that equipment.

414-4 Mix Design:

Approximately 300 pounds of produced mineral aggregate, in proportion to the anticipated percent usage, shall be obtained by the contractor and witnessed by the Engineer so that both parties are satisfied that samples are representative of the mineral aggregate to be utilized in the asphaltic concrete production.

The contractor shall also furnish representative samples of the following materials: a five-pound sample of the crumb rubber proposed for use, one gallon of asphalt cement from the intended supplier, three gallons of the proposed mixture of asphalt and rubber, and a one-gallon can of the mineral admixture to be used in the asphaltic concrete.

Along with the samples furnished for mix design testing, the contractor shall submit a letter explaining in detail its methods of producing mineral aggregate including wasting, washing, blending, proportioning, etc., and any special or limiting conditions it may propose. The contractor’s letter shall also state the source(s) of mineral aggregate, the source of asphalt cement and crumb rubber, the asphalt-rubber supplier, and the source and type of mineral admixture.

Within 10 working days of receipt of all samples and the contractor's letter in the Central Laboratory, the Department will provide the contractor with the percentage of asphalt-rubber to be used in the mix, the percentage to be used from each of the stockpiles of mineral aggregate, the composite mineral aggregate gradation, the composite mineral aggregate and mineral admixture gradation, and any special or limiting conditions for the use of the mix.

The Department will provide the contractor material to be used for calibration of nuclear asphalt content gauges. The material will be fabricated by the Department utilizing asphalt-rubber submitted by the contractor for mix design purposes.

414-5 Mix Design Revisions:

The contractor shall not change its methods of crushing, screening, washing, or stockpiling from those used during production of material used for mix design purposes without approval of the Engineer, or without requesting a new mix design.

During production of asphaltic concrete, the contractor, on the basis of field test results, may request a change to the approved mix design. The Engineer will evaluate the proposed changes and notify the contractor of the Engineer’s decision within two working days of the receipt of the request.

If, at any time, unapproved changes are made in the source of bituminous material, source(s) of mineral aggregate, production methods, or proportional changes in violation of approved mix design stipulations, production shall cease until a new mix design is developed, or the contractor complies with the approved mix design.

At any time after the mix design has been approved, the contractor may request a new mix design.

The costs associated with the testing of materials in the developing of mix designs after a mix design acceptable to the Department has been developed shall be borne by the contractor.

If, during production, the Engineer on the basis of testing determines that a change in the mix design is necessary, the Engineer will issue a revised mix design. Should these changes require revisions to the contractor's operations which result in additional cost to the contractor, it will be reimbursed for these costs. However, the Engineer reserves the right to modify the asphalt-rubber content without compensation being made to the contractor involving additional operation costs.

414-6 Acceptance of Materials:

414-6.01 General:

If the production of asphaltic concrete is stopped either for failure to meet the requirements specified hereinafter under Subsection 414-6.03, or because changes are made in the mix design, samples will be taken for calculating new consecutive averages either after production resumes or after the changes in the mix design have been made. The acceptance of the mineral aggregate gradation and the bituminous material content will be determined on the basis of the tests as hereinafter specified under Subsection 414-6.03. The Engineer reserves the right to increase the frequency of sampling and testing upon the resumption of asphaltic concrete production.

414-6.02 Mineral Aggregate:

Aggregate shall be free of deleterious materials, clay balls, and adhering films or other material that prevent thorough coating of the aggregate with the bituminous material.

During asphaltic concrete production, the Engineer shall obtain and test samples of mineral aggregate for the determination of the sand equivalent, fractured coarse aggregate particles, and flakiness index. The sample shall be obtained either from the cold feed prior to addition of mineral admixture, or from the stockpiles. Should such testing indicate results not meeting the requirements of Table 414-2 for sand equivalent, fractured coarse aggregate particles, and flakiness index, operations shall cease and the contractor shall have the option of requesting a new mix design or correcting deficiencies in the aggregate stockpiles.

414-6.03 Asphaltic Concrete:

(A) Mineral Aggregate Gradation:

For each approximate 500 tons of asphaltic concrete, at least one sample of mineral aggregate will be taken. Samples will be taken in accordance with the requirements of Arizona Test Method 105 on a random basis just prior to the addition of mineral admixture and bituminous material by means of a sampling device which is capable of producing samples which are representative of the mineral aggregate. The device, which shall be approved by the Engineer, shall be furnished by the contractor. In any shift that the production of asphaltic concrete is less than 500 tons, at least one sample will be taken.

Samples will be tested for conformance with the mix design gradation without mineral admixture in accordance with the requirements of Arizona Test Method 201.

The gradation of the mineral aggregate will be considered to be acceptable, unless the average of any three consecutive tests or the result of any single test varies from the mix design gradation percentages as follows:

Passing Sieve	**Number of Tests**	
	3 Consecutive	**One**
No. 4	± 4	± 6
No. 8	± 3	± 4
No. 200	± 1.0	± 1.5

One hundred percent of the material shall pass the largest sieve size shown in Table 414-1.

At any time that test results indicate that the gradation of the mineral aggregate does not fall within all of the limits indicated, the production of asphaltic concrete shall cease immediately and shall not begin again until a calibration test indicates that the gradation is within the 3-consecutive test limits indicated.

(B) Asphalt-Rubber Content:

During production of asphaltic concrete, the contractor shall maintain at the plant site a nuclear asphalt content gauge calibrated and operated in accordance with Arizona Test Method 421. The calibration shall be performed using material supplied by the Department as stated in Section 414-4. Under the observation of the Engineer, the contractor shall determine the asphalt-rubber content by means of the nuclear asphalt content gauge a minimum of four times per full shift. The contractor's technicians performing the testing, including the calibration of the nuclear gauge, shall meet the technician requirements given in the Department's System for the Evaluation of Testing Laboratories. The requirements may be obtained from ADOT Materials Group, 1221 North 21st Avenue, Phoenix, AZ 85009. Production of asphaltic concrete shall cease immediately and the plant and/or the nuclear asphalt content gauges re-calibrated if the Engineer determines the percent of asphalt-rubber has varied by an amount greater than ± 0.5 percent from the amount directed by the Engineer.

414-7 Construction Requirements:

414-7.01 Quality Control:

Quality control of mineral aggregate production and asphaltic concrete production shall be the responsibility of the contractor. The contractor shall perform sufficient testing to assure that mineral aggregate and asphaltic concrete are produced which meet all specified requirements. The Engineer reserves the right to obtain samples of any portion of any material at any point of the operations for the Engineer's own use.

414-7.02 Stockpiling:

The contractor will not be allowed to feed the hot plant from stockpiles containing less than two full days of production unless only two days production remain to be done or special conditions exist where the Engineer deems this requirement waived.

Mineral aggregate shall be separated and stockpiled so that segregation is minimized. An approved divider of sufficient size to prevent intermingling of stockpiles shall be provided.

414-7.03 Proportioning:

The contractor shall provide documentation by calibration charts or other approved means that the mineral aggregate, asphalt-rubber, and mineral admixture are being proportioned in accordance with the approved mix design.

Unless approved by the Engineer, no individual stockpile usage shall be less than three percent of the total mineral aggregate.

Changes in stockpile/hot bin use in excess of five percent from the approved mix design will not be permitted without the approval of the Engineer.

Mineral admixture shall be mechanically mixed with the mineral aggregate prior to combining the mineral aggregate and asphalt-rubber. The engineer may direct a spray of water be applied either to control the loss of the mineral admixture or to comply with any mix design requirements for wet mixing of the aggregate and admixture.

If a drum mix plant is used, the mineral admixture shall be added and thoroughly mixed by means of a mechanical mixing device prior to the mixture entering the drum drier. The mineral admixture shall be weighed across a weigh belt or an approved alternative weighing system, with a weight totalizer prior to entry into the mechanical mixing device. The mechanical mixing device shall be a pugmill type mixer consisting of at least two motorized shafts with mixing paddles. The mixing device shall be designed such that the mixture of aggregate and admixture is moved in a near horizontal direction by the mixing paddles without the aid of conveyor belts for a distance of at least three feet. Mixing devices which permit the mixture of aggregate and admixture to fall through mixing blades onto a belt or chute are not acceptable. The mixing device's rated capacity in tons per hour shall not be exceeded by the rate of material feed to the mixer. The mixer shall be constructed to prevent the leakage of the contents. The mixer shall be located in the system at a location where the mixed material can be readily inspected on a belt prior to entry into the drum. The mixing device shall be capable of effective mixing in the full range of asphaltic concrete production rates.

A positive signal system and a limit switch device shall be installed in the plant at the point of introduction of the admixture. The positive signal system shall be placed between the metering device and the drum drier, and utilized during production whereby the mixing shall automatically be stopped if the admixture is not being introduced into the mixture.

If a batch plant is used, the mineral admixture shall be added and thoroughly mixed in the pugmill prior to adding asphalt-rubber.

The contractor shall furnish daily documentation to the Engineer that the required amount of mineral admixture has been incorporated into the asphaltic concrete.

No fine material which has been collected in the dust collection system shall be returned to the mixture unless the Engineer, on the basis of tests, determines that all or a portion of the collected fines can be utilized. If the Engineer so determines, the Engineer will authorize in writing the utilization of a specific proportion of the fines; however, authorization will not be granted unless the collected fines are uniformly metered into the mixture.

Mineral aggregate, mineral admixture, and asphalt-rubber shall be proportioned by volume, by weight, or by a combination of volume and weight.

When mineral aggregate, mineral admixture, and asphalt-rubber are proportioned by weight, all boxes, hoppers, buckets, or similar receptacles used for weighing materials, together with scales of any kind used in batching materials, shall be insulated against the vibration or movement of the rest of the plant due to the operation of any equipment so that the error in weighing with the entire plant operating shall not exceed two percent for any setting nor 1-1/2 percent for any batch. Bituminous material shall be weighed in a heated, insulated bucket suspended from a springless dial scale system.

When mineral aggregate, mineral admixture, and asphalt-rubber are proportioned by volume, the correct portion of each mineral aggregate size introduced into the mixture shall be drawn from the storage bins by an approved type of continuous feeder which will supply the correct amount of mineral aggregate in proportion to the bituminous material and so arranged that the proportion of each mineral aggregate size can be separately adjusted. The continuous feeder for the mineral aggregate shall be mechanically or electrically actuated.

The introduction of asphalt-rubber shall be controlled by an automated system fully integrated with the controls for mineral aggregate and mineral admixture.

414-7.04 Drying and Heating:

A recording pyrometer or other approved recording thermometric instrument sensitive to a rate of temperature change not less than 10 degrees F per minute shall be so placed at the discharge chute of the drier in order to record automatically the temperature of the asphaltic concrete or mineral aggregate. A copy of the recording shall be given to the Engineer at the end of each shift.

The moisture content of the asphaltic concrete shall not exceed 0.5 percent. The moisture content will be determined in accordance with Arizona Test Method 406. Drying and heating shall be accomplished in such a manner as to preclude the mineral aggregate from becoming coated with fuel oil or carbon.

414-7.05 Mixing:

The production of the plant shall be governed by the rate required to obtain a thorough and uniform mixture of the materials.

A positive signal system shall be provided to indicate the low level of mineral aggregate in the bins. The plant will not be permitted to operate unless this signal system is in good working condition. Each bin shall have an overflow chute or a divider to prevent material from spilling into adjacent bins.

The temperature of asphaltic concrete upon discharge from the mixer shall not exceed 350 degrees F. If the asphaltic concrete is discharged from the mixer into a hopper, the hopper shall be constructed so that segregation of the asphaltic concrete will be minimized.

414-7.06 Placing and Finishing:

(A) General Requirements:

The handling of asphaltic concrete shall at all times be such as to minimize segregation. Any asphaltic concrete which displays segregation shall be removed and replaced.

Before asphaltic concrete is placed, the surface to be paved shall be cleaned of all objectionable material and tacked with asphalt cement in accordance with the requirements of Section 404 of the specifications. The cleaning of the surface, the tacking of the surface, and the amount and grade of asphalt cement used shall be as directed by and acceptable to the Engineer.

Unless otherwise specified on the project plans, asphaltic concrete shall not be placed on the two-foot widened section where guardrail is to be installed.

(1) Dates and Surface Temperature:

Asphaltic concrete shall be placed between the dates specified in the Special Provisions and only when the temperature of the surface on which the asphaltic concrete is to be placed is at least 85 ^{o}F.

Despite a surface temperature of 85 ^{o}F, the Engineer at any time may require that the work cease or that the work day be reduced in the event of weather conditions either existing or expected which would have an adverse effect upon the asphaltic concrete.

(2) Delivery to Screed Unit:

Asphaltic concrete delivered to the screed unit shall be a free flowing, homogeneous mass in which there is no segregation, crusts, lumps, or migration of the asphalt-rubber.

Should any one or more of such conditions be evident in the material delivered to the screed unit, and which cannot be eliminated by one or more of the following methods, the Engineer will order the work to be stopped until conditions are conducive to the delivery of the material in the condition as hereinbefore required:

(a) Covering hauling units with tarpaulins.

(b) Dumping material directly into the paver.

(c) Moving the hot plant nearer to the point of delivery.

Other measures proposed by the contractor which will deliver asphaltic concrete meeting the above requirements will be considered by the Engineer.

(B) Loading Asphaltic Concrete into the Paving Machine:

If the asphaltic concrete is dumped directly into the paving machine from the hauling trucks, care shall be taken to avoid jarring the machine or moving it out of alignment. No vertical load shall be exerted on the paving machine by the trucks. Trucks, while dumping, shall be securely attached to the paving machine.

If the asphaltic concrete is dumped upon the surface being paved and subsequently loaded into the paving machine, it shall not be dumped at a distance greater than 150 feet in front of the paving machine. The loading equipment shall be self-supporting and shall not exert any vertical load on the paving machine. Substantially all of the asphaltic concrete shall be picked up and loaded into the paving machine.

(C) Placing and Finishing Asphaltic Concrete by Means of Self-Propelled Paving Machines:

All courses of asphaltic concrete shall be placed and finished by means of self-propelled paving machines except under certain conditions or at certain locations where the Engineer deems the use of self-propelled paving machines impractical.

In order to achieve, as far as practical, a continuous operation, the speed of the paving machine shall be coordinated with the production of the plant. If the paving machine is stopped for more than three minutes, or there is a three-minute or longer interval between the completion of delivery by one truck and the beginning of delivery by the next truck, the paving machine shall be pulled away from the mat in order for the rollers to compact this area in accordance with the temperature limitations given hereinafter under Subsection 414-7.08(C). A transverse construction joint shall be made by a method approved by the Engineer.

Self-propelled paving machines shall spread the mixture without segregation or tearing within the specified tolerances, true to the line, grade, and crown indicated on the project plans. Pavers shall be equipped with hoppers and augers which will distribute the mixture uniformly in front of adjustable screeds.

Screeds shall include any strike-off device operated by tamping or vibrating action which is effective without tearing, shoving or gouging the mixture and which produces a course with a uniform texture and density for the full width being paved. Screeds shall be adjustable as to height and crown and shall be equipped with a controlled heating device for use when required.

Tapered sections not exceeding eight feet in width, or widened sections not exceeding four feet in width may be placed and finished by other means approved by the Engineer.

(D) Automatically Actuated Control System:

Except under certain conditions or at certain locations where the Engineer deems the use of automatic controls impractical, all courses of asphaltic concrete shall be placed and finished by means of self-propelled paving machines equipped with an automatically actuated control system.

The control system shall control the elevation of the screed at each end by controlling the elevation of one end directly and the other end indirectly either through controlling the transverse slope or alternately when directed, by controlling the elevation of each end independently.

The control system shall be capable of working with the following devices which shall be furnished with the machine:

Ski-type device at least 30 feet in length, supported throughout its entire length.

Short ski.

Failure of the control system to function properly shall be cause for the suspension of the asphaltic concrete operations.

414-7.07 Joints:

If the lift thickness is equal to or greater than one inch, the contractor shall schedule its paving operations to minimize exposed longitudinal edges. Unless otherwise approved by the Engineer, the contractor shall limit the placement of asphaltic concrete courses, in advance of adjacent courses, to one shift of asphaltic concrete production. The contractor shall schedule its paving operations in such a manner to eliminate exposed longitudinal edges over weekends or holidays.

Longitudinal joints shall be located within one foot of the centerline between two adjacent lanes.

Before a surface course is placed in contact with a cold transverse construction joint, the cold existing asphaltic concrete shall be trimmed to a vertical face by cutting the existing asphaltic concrete back for its full depth and exposing a fresh face. After placement and finishing of the new asphaltic concrete, both sides of the joint shall be dense and the joint shall be well sealed. The surface in the area of the joint shall conform to the requirements hereinafter specified for surface tolerances when tested with the straightedge placed across the joint.

414-7.08 Compaction:

(A) General Requirements:

The temperature of asphaltic concrete just prior to compaction shall be at least 275 degrees F.

The wheels of compactors shall be wetted with water, or if necessary soapy water, or a product approved by the Engineer to prevent the asphaltic concrete from sticking to the steel wheels during rolling. The Engineer may change the rolling procedure if in the Engineer's judgment the change is necessary to prevent picking up of the asphaltic concrete.

(B) Equipment:

A minimum of three static steel wheel compactors shall be provided. The drums shall be of sufficient width that when staggered, two compactors can cover the entire width of the ribbon with one pass.

The compactors shall weigh not less than eight tons.

The compactors shall be self-propelled and shall be operated with the drive wheel in the forward position. Vibrator rollers may be used in the static mode only.

(C) Rolling Procedure:

Two compactors shall be used for initial breakdown and be maintained no more than 300 feet behind the paving machine. The roller(s) for final compaction shall follow as closely behind the initial breakdown as possible. As many passes as is possible shall be made with the compactors before the temperature of the asphaltic concrete falls below 220 ^{o}F

414-7.09 Surface Requirements and Tolerances:

Asphaltic concrete shall be compacted as required, smooth and reasonably true to the required lines, grades, and dimensions.

Asphaltic concrete shall not vary more than 1/8 inch from the lower edge of a ten-foot straightedge when the straightedge is placed parallel to the center line of the roadway, or 1/4 inch when placed in the transverse direction across longitudinal joints.

414-7.10 Acceptance:

Asphaltic concrete will be accepted complete in place, if, in the judgment of the Engineer, the asphaltic concrete reasonably conforms to the requirements specified herein. Asphaltic concrete that is not acceptable and is rejected shall be replaced to the satisfaction of the Engineer and at no expense to the Department.

414-8 Method of Measurement:

Asphaltic concrete will be measured by the ton for the mixture actually used, which will include the weight of mineral aggregate, mineral admixture and asphalt-rubber. Measurement will include any weight used in construction of intersections, turnouts, or other miscellaneous items or surfaces.

Asphalt-rubber will be measured by the ton.

The weight of the asphalt-rubber material shall either be determined by weighing directly enroute from the reaction vessel to the point of delivery or be determined from the weight of the asphalt cement and the weight of the rubber minus wastage.

Mineral admixture will be measured by the ton.

414-9 Basis of Payment:

The accepted quantities of asphaltic concrete, measured as provided above, will be paid for at the contract unit price per ton, which price shall be full compensation for the work, complete in place, as specified herein.

Payment for the asphalt-rubber will be made by the ton, including asphalt cement and crumb rubber. The results of a nuclear asphalt content gauge shall not be used to determine the weight of asphalt-rubber material as the basis of payment.

Payment for mineral admixture will be made by the ton.